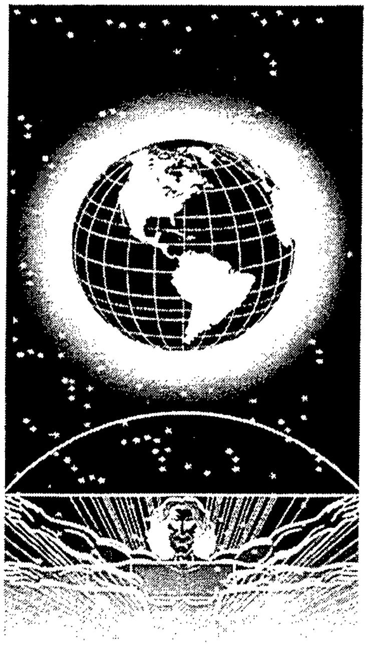
AFRL-HE-WP-TR-2002-0059



UNITED STATES AIR FORCE RESEARCH LABORATORY

Integrated Technical Information for the Air Logistics Centers (ITI-ALC) Phase I Final Report

Ron Kelly

Systems Research and Applications Corporation
4031 Colonel Glenn Highway, Suite 100
Beavercreek, OH 45431

Barbara L. Masquelier
Air Force Research Laboratory

April 1996

Final Report for the Period March 1994 to April 1996

Human Effectiveness Directorate
Deployment and Sustainment Division
Logistics Readiness Branch
2698 G Street
Wright-Patterson AFB OH 45433-7604

NOTICES

When US Government drawings, specifications or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Air Force Research Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Federal Government agencies registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
8725 John J. Kingman Rd., Ste 0944
Ft. Belvoir, VA 22060-6218

DISCLAIMER

This Technical Report is published as received and has not been edited by the Air Force Research Laboratory, Human Effectiveness Directorate.

TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-TR-2002-0059

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Mark M. Hoffman

MARK M. HOFFMAN
Deputy Chief
Deployment and Sustainment Division
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1996	Final - March 1994 - April 1996

4. TITLE AND SUBTITLE
Integrated Technical Information for the Air Logistics Centers (ITI-ALC)
Phase I Final Report

5. FUNDING NUMBERS
C: F41624-94-C-5021
PE: 63106F
PR: 2950
TA: 00
WU: 26

6. AUTHOR(S)
Ron Kelly, Barbara L. Masquelier

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Systems Research and Applications Corporation
4031 Colonel Glenn Highway, Suite 100
Beavercreek, OH 45431

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory, Human Effectiveness Directorate
Deployment and Sustainment Division
Air Force Materiel Command
Logistics Readiness Branch
Wright-Patterson AFB, OH 45433-7604

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-HE-WP-TR-2002-0059

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The objective of the Integrated Technical Information for the Air Logistics Centers (ITI-ALC) program was to improve the efficiency and effectiveness of the Air Force's depot maintenance process, with specific emphasis on Programmed Depot Maintenance (PDM) operations and with a limited look at component repair. This was accomplished by streamlining the process and developing an ITI-ALC integrated systems concept implementable with technologies that will automate the streamlined process to standardize, integrate, and make information easily accessible to the ALC personnel through a single entry source. This integration of information included interfacing with many independent sources of information such as engineering drawings, maintenance plans, manufacturing specifications, technical orders, and dynamic diagnostics. When implemented, the results of the ITI-ALC program will reduce flow days, improve quality, reduce operating costs, and improve mechanic performance. The ITI-ALC program was accomplished through the application of a structured, user-focused methodology that supported the effective collection, integration, and analysis of the user information. The approach produced effective and practical business process improvement (BPI) concepts for the streamlined PDM process and the requirements for the supporting ITI-ALC system. This report describes the methodology that was applied to successfully satisfy the requirements of the ITI-ALC program along with possible recommendations and/or lessons learned during the performance of the ITI-ALC program.

14. SUBJECT TERMS
Integrated Technical Information for the Air Logistics Centers (ITI-ALC)
Aircraft Depot Maintenance Depots Information Logistics
Maintenance Technicians Workload

15. NUMBER OF PAGES
122

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

THIS PAGE INTENTIONALLY LEFT BLANK

PREFACE

The Integrated Technical Information for the Air Logistics Centers (ITI-ALC) Final Documentation presented in this report was prepared under Government contract F41624-94-C-5021 in accordance with Contract Data Requirements List (CDRL) sequence number A009. This report reflects the work accomplished by Systems Research and Applications (SRA) Corporation and ARINC Research Corporation, and sponsored by Armstrong Laboratory/Logistics Research Division, Operational Logistics Branch (AL/HRGO), Wright-Patterson Air Force Base (AFB), OH. This report was developed under the leadership of Ms. Barbara Masqueilier, the AL/HRGO Program Manager, and Mr. Ron Kelly, the SRA Corporation Principal Investigator for the ITI-ALC program.

During this first phase of the ITI-ALC program, the ITI-ALC team visited the Air Logistics Centers (ALCs) to collect data required to document the current Programmed Depot Maintenance (PDM) process, to validate our understanding of the process, and to review and enhance the improvement concepts for the PDM process and ITI-ALC system. This user involvement played a significant role to ensure that the improved PDM capability will result in significant benefits to depot personnel. The ITI-ALC team expresses its appreciation for the valuable cooperation, contributions, and support received from the personnel within the following depots:

- Ogden Air Logistic Center (OO-ALC)
- Oklahoma Air Logistic Center (OC-ALC)
- Sacramento Air Logistic Center (SM-ALC)
- San Antonio Air Logistic Center (SA-ALC)
- Warner-Robins Air Logistic Center (WR-ALC)

CONTENTS

CONTENTS (Continued)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

1. SUMMARY

The eve of the 21st century marks more than a chronological milestone. Converging changes in technology and economics, and fundamental restructing and downsizing of the military call for fresh thinking about how to harness information technology to provide tangible value to organizations and users. The challenge is to adapt organizations and processes to rapidly changing technologies and methodologies to achieve greater effectiveness and quality at reduced cost. Organizations that master change will realize their goals, while those who fail to reengineer their policies and practices will diminish in stature and gradually fade away.

The ALCs are poised on the forward edge of military readiness. Budget realities demand that older and often heavily modified aircraft remain in the inventory longer; thus increasing the importance of cost-effective, improved depot maintenance. These improvements require that better, more timely, and seamlessly integrated information -- information currently resident in numerous systems -- be made available to the depot-level mechanics, managers, and planners.

The budget austerity that spawned the current emphasis on functional process improvements and reengineered business practices is not likely to abate. Managers in every organization must objectively rethink their current processes and challenge the status quo. Merely injecting technology without improving the underlying processes yields marginal, short-term improvements -- not the type of fundamental breakthroughs that are imperative if the ALCs are to do more for less. Only by reengineering its operations can the Air Force realize the hoped-for productivity and quality improvements that are needed to meet its mission.

The ITI-ALC program was established to address these objectives of integrating and delivering the information required in the depot maintenance process. Specifically, the ITI-ALC initiative focused on developing an improved process definition for the PDM aspect of depot maintenance with a limited look at component repair, and the requirements and specification for the ITI-ALC system to automate and support the implementation of the improved process. This improved process and the ITI-ALC system will help to standardize and integrate maintenance processes and information not only within a depot but also across the depots.

The improved process and the applications of technologies for the depot maintenance process was developed using a structured, user-focused methodology that included active participation by maintenance personnel from all five ALCs. Through this active participation, information about the current process was collected, along with user-identified problems and improvement ideas. This user-specified information was analyzed and aggregated into a set of "AS-IS" models which represented a unified view of the current depot maintenance processes. This "AS-IS" view was validated by the users to ensure a solid foundation on which to build the improved "TO-BE" concept for the depot maintenance process.

Analysis of the "AS-IS" depot maintenance process identified problem areas and potential improvement opportunities. Combining these identified problem areas and potential improvement opportunities with those suggested by the users, a set of 15 Business Process Improvements (BPIs) were identified that impacted a range of depot maintenance characteristics.

These characteristics listed in Figure 1-1, include role changes for personnel, data changes based on the commonality of data within as well as across the ALCs, process changes to streamline depot maintenance, organizational changes to focus attention on the ultimate goal of getting aircraft repaired, and policy changes that support rather than hinder the improved depot maintenance process per the performance targets.

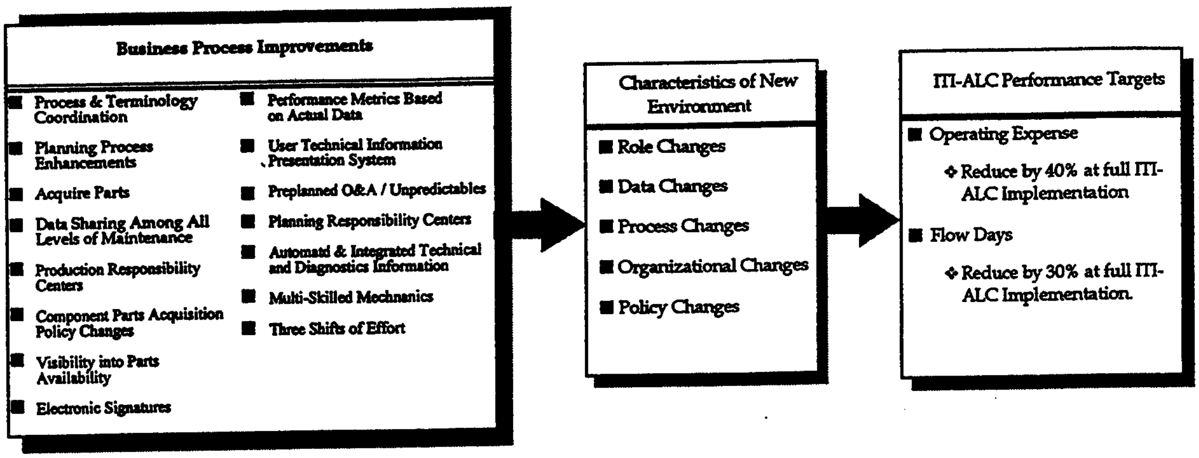


Figure 1-1. The BPIs Translate into Operational Savings

With the requirements and specifications for the improved process established, the requirements for the supporting ITI-ALC system were developed, along with its high-level design.

A business case formed the basis to quantify the improvement benefits. The values of the benefits were based on various levels of the ITI-ALC system implementation. These levels of implementation extended from implementing the improved process without the ITI-ALC system to full implementation of the ITI-ALC system to support the improved process. As represented in Figure 1-1, full implementation of the improved PDM process and the supporting ITI-ALC system providing realistic savings of 40% in operational expenses and 30% in aircraft maintenance flow days.

The structured, user-focused methodology applied to the ITI-ALC program has been developed and improved over a number of years and applications. During its application on the ITI-ALC program, additional lessons were learned with respect to its strengths, weaknesses, and improvement ideas for its next applications. The following list summarizes possible recommendations and/or lessons learned that were identified during Phase I of the ITI-ALC program. Section 3 provides more detail on possible recommendations and/or lessons learned that were identified as part of each project entity; such as, the various models and formal deliverables. This list of possible recommendations and/or lessons learned is repeated in Appendix C.

- **Significant preparation for the data collection trips is critical.**

  User acceptance is critical to any system development effort. Because the data collection trips were the first technical interface with the users and because humans have a tendency to let "first impressions be lasting impressions," the data collection trips provided the first and best opportunity to gain the users' acceptance of and involvement in the ITI-ALC program. The data collection trips were well planned as determined by the positive feedback and involvement received from the ALC personnel.

- **The model development order must be such that the benefits of their integration is fully utilized.**

  The methodology applied to the ITI-ALC program was based on the development and analysis of an integrated set of models and reports documenting the requirements, specifications, design, and benefits predicted from implementing the improved process and the ITI-ALC system. The models developed for this methodology were the following:

  - "AS-IS" and "TO-BE" Functional Models,
  - "AS-IS" and "TO-BE" Data Models,
  - "AS-IS" and "TO-BE" Process Models,
  - "AS-IS" and "TO-BE" Simulation Models, and
  - System Model.

  The reports developed were the ITI-ALC Business Case, System/Segment Specification (SSS), and the System/Segment Design Document (SSDD). The development order of these items was good, but minor adjustments would have improved the effective performance of the ITI-ALC program. Of specific importance was the development and analysis of the process flow and simulation models. Having established the requirements for these models and analyses earlier in the program would have reduced some of the duplicative data collection efforts.

- **Validation difficulty varied among the various artifacts developed.**

  The various "AS-IS" and "TO-BE" models, which formed the foundation for the program, required significant time and effort for validation by the functional experts and users. These validation efforts were implemented using the readership cycle and on-site walkthroughs. While the review results were sufficient for validation, the validation of the SSS handled as a workshop away from the ALC worksite proved to be more productive. Therefore, the use of similar workshops for the "AS-IS" and "TO-BE" models would be recommended.

- **Data flow diagrams are an excellent way to represent the system model.**

  The top-down approach supported by data flow diagrams provided gradual, controlled concept of operation for the ITI-ALC system. This approach also provided a direct link of information from the functional and data models, thereby, supporting the requirement for the traceability of information through the models. While the concept of using data flow diagrams was effective, the System Architecture tool used to developed these diagrams had some short comings that need to be corrected to better support data flow diagram development.

- **The concept of developing and using process flow diagrams via the Integrated DEFinition ($IDEF_3$) notation and simulation via WITNESS was value added to the overall ITI-ALC program.**

  The development of the process flow diagrams was facilitated by the existence of the functional models while the development of the process flow models helped to increase the accuracy and completeness of the functional models. The process model provided an effective structure to identify and collect the performance information required from simulation and provided an effective structure for developing and depicting the simulations.

- **The tools used to implement the process flow model and the translation to simulation are not yet mature.**

  The translation capability from ProSim™ to WITNESS® was not complete. The transfer from ProSim to WITNESS required a significant amount of additional data and data manipulation in WITNESS before the process flow could be exercised using WITNESS. During the ITI-ALC program, this ineffective transfer of information was overcome by developing an in-depth understanding of the transfer requirements and accomplishing much of it manually.

  The translation from the process description to the simulation was one-directional. The intent of $IDEF_3$, as implemented via ProSim, is to collect process flow and performance information so as to facilitate the development and execution of a simulation model within WITNESS. However, because significant effort is required to complete the simulation model in WITNESS, the value of the $IDEF_3$ model via ProSim is significantly reduced once the first translation is accomplished. During the ITI-ALC program, this situation was addressed by maintaining the $IDEF_3$/ProSim representation for display of the network while adjusting the model within WITNESS as needed for the simulation.

  The process model notation, as represented by ProSim, was not an effective presentation vehicle for two reasons. First, the information presented on a process flow network was very limited, making it a labor intensive effort to read and analyze a process flow. Second, the amount of readable information printed on one page was limited, forcing the model to be developed in short segments. Connecting the short segments to form and effectively depict a larger process was difficult. This difficulty was reduced by using the functional model and performance data sheets to supplement the use of the process flow represented via ProSim.

- **An integrated team effort is required to maximize the quality of the BPIs and the products developed throughout the program.**

  Throughout the performance of the ITI-ALC program communication among the team members was important to ensure a unified understanding of the "AS-IS" and "TO-BE" depot maintenance processes, and was critical during the development of the System Model (SM), SSS, and SSDD. Even though the SM, SSS, and SSDD developments are based on the "TO-BE" models, the interpretation of the models can vary slightly, causing potential inconsistencies among these artifacts. Close interactions among the developers of all the program artifacts, and especially the SM, SSS, and SSDD maximized the effectiveness of the ITI-ALC system requirements, and high-level design.

1.1 INTRODUCTION

The objective of the ITI-ALC program was to improve the efficiency and effectiveness of the Air Force's depot maintenance process, with specific emphasis on PDM operations and with a limited look at component repair. This was accomplished by streamlining the process and developing an ITI-ALC integrated system concept implementable with technologies that will automate the streamlined process to standardize, integrate, and make information easily accessible to the ALC personnel through a single entry source. This integration of information included interfacing with many independent sources of information such as engineering drawings, maintenance plans, manufacturing specifications, technical orders, and dynamic diagnostics. When implemented, the results of the ITI-ALC program will reduce flow days, improve quality, reduce operating costs, and improve mechanic performance.

The ITI-ALC program was accomplished through the application of a structured, user-focused methodology that supported the effective collection, integration, and analysis of the user information. The approach produced effective and practical BPI concepts for the streamlined PDM process and the requirements for the supporting ITI-ALC system.

During the ITI-ALC program, the team visited all five of the Air Force's ALCs, as well as some commercial depot centers, to support the data collection, model development, process and system specification, and validation process. These direct interactions with the users included initial interviews with 139 users and follow-up interviews with 38 users for a total of 177 data collection interviews. Furthermore, the interaction began in the interviews was continued by model readership (103 total reviews), validation meetings (29 user representatives), and a user workshop (10 user representatives).

This report describes the methodology that was applied to successfully satisfy the requirements of the ITI-ALC program along with possible recommendations and/or lessons learned during the performance of the ITI-ALC program. To facilitate the reading of this report, it is divided into sections containing two levels of detail. Section 2 presents an overview of the methodology, Section 3 presents more details about each aspect of the methodology along with possible recommendations and/or lessons learned related to the major stages that make up the methodology, and Section 4 presents conclusions and recommendations.

1.2 BACKGROUND

Depot maintenance is responsible for all the scheduled and unscheduled maintenance of aircraft, other aerospace vehicles, and associated systems and components, such as engines and landing gears. An effective depot maintenance process provides the operating organizations with sufficient quantities of aircraft and serviceable items to train aircrews in peacetime and to fly missions in the event of war. While recent improvements in system reliability are reducing the time required for an item to come into the depot process, budgets for new systems, spares, and mechanic training are decreasing. Therefore, the requirement to use more effective and efficient ways to accomplish the depot maintenance process is more critical today than ever before.

Computer and information technology advances have driven many projects to improve information access within and among maintenance organizations. Other projects have been directed to improve tools and maintenance aids for mechanics. Until now, however, no attempt has been made to integrate the available information, tools, and aids for the mechanic. The ITI-ALC program goal was to integrate these elements by focusing on the maintenance mechanic's needs as the most important aspect of this integration process. This integration was accomplished through the design of a streamlined depot maintenance process along with the ITI-ALC system to facilitate the performance of the streamlined depot maintenance process. Thus, the ultimate value of the ITI-ALC system and its acceptance by the end-user is directly linked to the ITI-ALC program's ability to achieve measurable performance improvements at the mechanic level. This user focus is the foundation for the systematic approach used by the ITI-ALC team to develop an ITI-ALC architecture.

The overall ITI-ALC program is represented in Figure 1-2, with the goal of the first phase being to develop the specifications and design for the ITI-ALC system and the second phase to develop a demonstration or "proof of concept" system. The demonstration system will be evaluated with respect to the improvement predictions developed for the design. Any performance descrepancies are used to refine the design and the implementation until the acceptable ITI-ALC system is ready.

NOTE: This final report only pertains to Phase I of the overall ITI-ALC program.

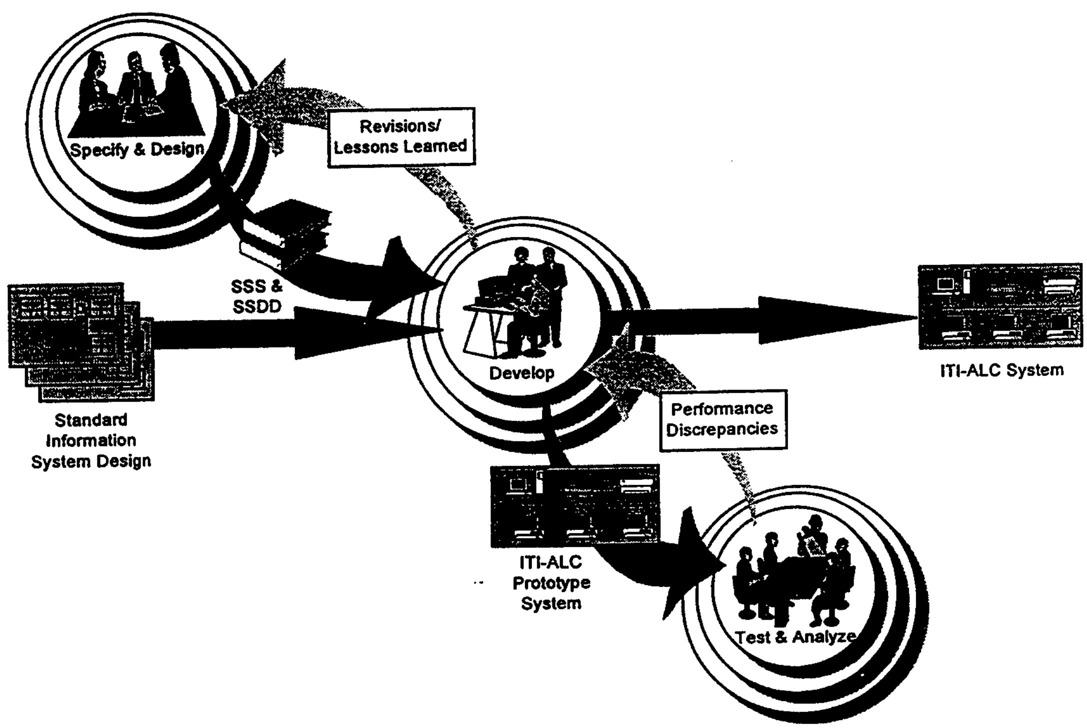


Figure 1-2. An Overview of the Total ITI-ALC Program Concept

2. METHODS AND ASSUMPTIONS

2.1 METHODS

The ITI-ALC program was performed successfully through the application of a user-focused methodology, as represented in Figure 2-1. Working closely with the users helped to understand the work performed within the five ALCs, provided a solid foundation for the BPI analysis effort, and provided the basis to present and gain acceptance of the improvement concepts as they were developed.

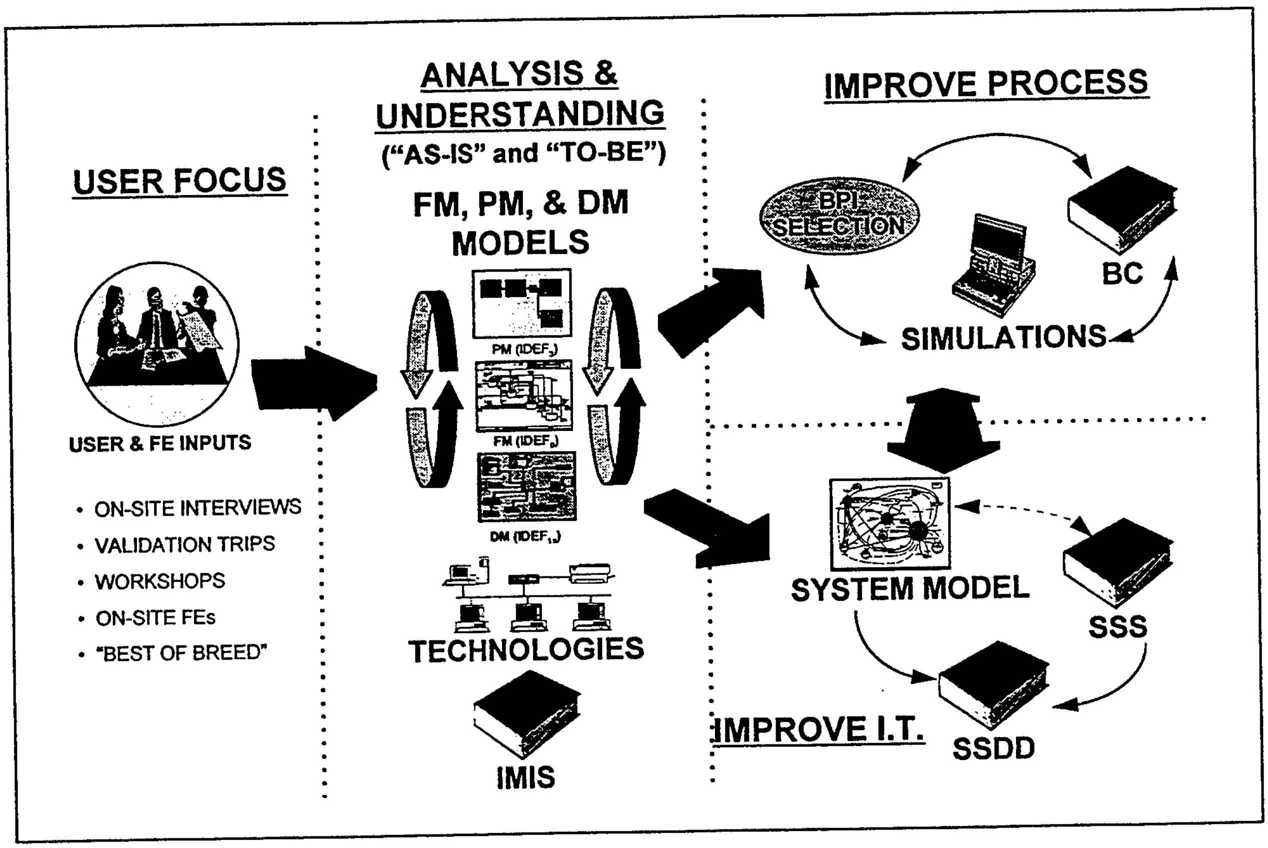


Figure 2-1. The ITI-ALC Program Methodology is User Focused

To obtain data needed to describe the current depot maintenance process, a data collection process consisting primarily of on-site interviews was implemented at each of the five ALCs. In addition, user ideas were also collected that identified what they believed was wrong with the process and how the process could be improved.

To effectively minimize the data collection effort required that a well defined set of data requirements be established. These data requirements were identified included activity-oriented data, interface-oriented data, and operations-oriented data. The activity-oriented data included activity definition information, inputs and outputs for the activities, and regulations and guidelines that defined the process of implementing the activities. Interface-oriented information included manual and automated interfaces among the personnel and organizations within the depot, and between the depot and supporting information systems. Operations-oriented data included performance definitions, process sequencing, and resource requirements data along with cost data. Finally, the problems and improvement related ideas from functional experts and users addressed a wide range of issues such as the identification of actual problems, symptoms of problems, personal dislikes about the process, duplication and non-productive aspects within the process, process adjustments, technology application, and process control.

The data collection approach was initiated with the development of a strawman model, in the format of a top-level $IDEF_0$ diagram. This strawman model provided the basis to understand the scope and process to be considered during the ITI-ALC analysis effort, and provided a vehicle for understanding and communicating the process among the team members.

The strawman model also provided the foundation on which to develop the question set needed to guide the data collection effort, to help select the information sites, and to identify the specific information sources. The strawman model also provided the structure around which the collected data was documented and retrieved during model development effort. The data collection effort itself was accomplished primarily using an interview approach, and supported by SRA's Data Collection Device (DCD). Refer to Appendix D for more details on data collection. The collected data was then systematically selected from the DCD, analyzed, and used to establish the "AS-IS" models which represented the PDM process from the three perspectives: functional, data, and process flow. The development of the "AS-IS" models was initiated first with the functional model, with the other model developments initiated shortly thereafter, and maintaining close coordination among the developments to ensure the traceability of requirements from the users through the models.

An analysis of these models, along with the user-identified process problems and improvement suggestions produced the BPI concepts, which in turn provided the basis for developing the corresponding set of "TO-BE" models. As with the "AS-IS" model development, the functional model provided the focal point for all the "TO-BE" model development; however, all the model development was coordinated to ensure completeness, consistency, and traceability of requirements.

The functional and processing requirements specified via the "TO-BE" models provided the criteria for identifying and selecting potential technologies for implementing the "TO-BE" PDM process. Using simulation and a business case analysis, a benefit-versus-cost trade-off analysis determined the value-added for each improvement concept and the selected technologies.

The ITI-ALC system functional requirements were derived from the "TO-BE" functional model and used to establish the SSS for the ITI-ALC system. In coordination with the development of the SSS, the specification for the ITI-ALC system was represented via the system model by using information from the benefit-versus-cost trade-off analysis, the functional requirements from the "TO-BE" functional model, and the data store definitions from the "TO-BE" data model. This specification identified the functionality of the ITI-ALC system, the data stores required, the interfaces between the ITI-ALC system and the users, the internal data stores, and the external data systems. Finally, information from both the system model and the SSS was used to develop the high-level design for the ITI-ALC system as represented in the SSDD.

Although there are many methods used to develop, analyze and utilize the different project entities and deliverables, two of the most important methods for any Business Process Reengineering (BPR) project are validation and traceability.

2.1.1 Validation Method

User-focused validation of all the models, BPIs, SSS and other systems engineering efforts were performed during their development to ensure their respective information was user oriented (see Figure 2-2). The "AS-IS" models were the first models to be validated.

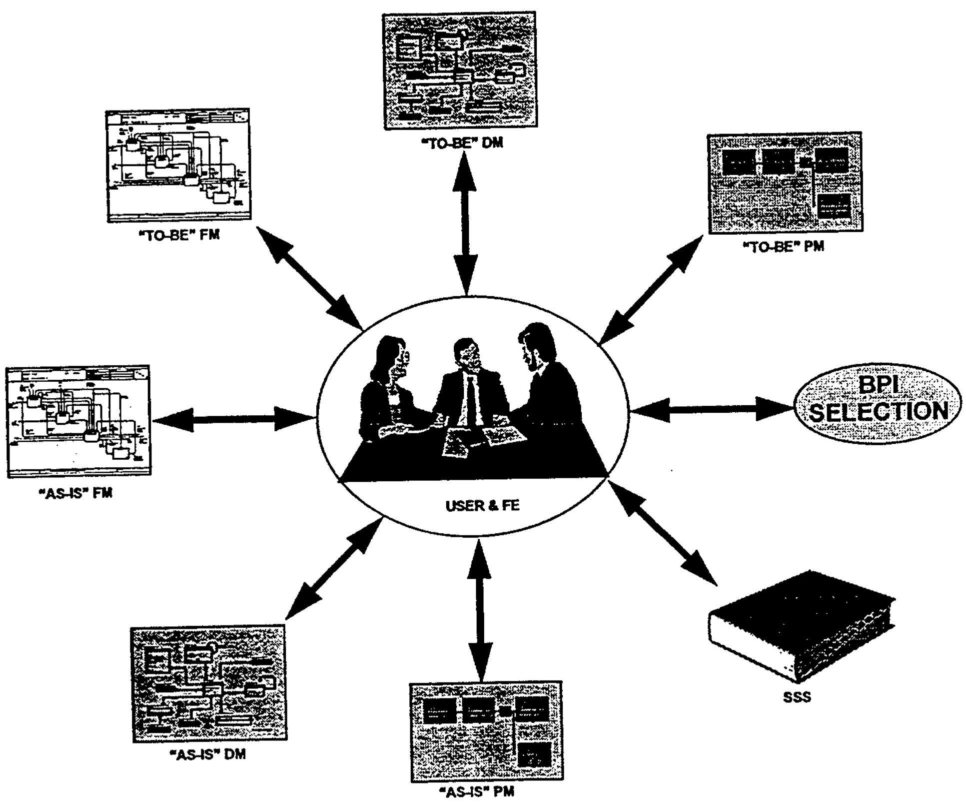


Figure 2-2. Validation is User-Focused

The validation of the "AS-IS" functional model began as integral part of its development. During the strawman development, scenario-based walkthroughs were held with functional area experts. During each data collection interview, the information collected from previous interviews was verified as well as new data being collected. As the model was being developed, a number of walkthroughs were performed and readership kits were distributed among the ITI-ALC team for model review. When relatively complete, readership kits were provided to the ARINC functional area experts at each ALC and their comments were used to refine the "AS-IS" models. A total of 58 reviews were done on this model before the formal walkthroughs were conducted at the

ALCs. The "AS-IS" functional model was then presented to a total of 45 depot maintenance personnel as part of the formal scenario walkthrough process.

Since the development of the "AS-IS" data model was based on the information specified in the "AS-IS" functional model, much of the validation of the data model was achieved as part of the validation of the functional model. To complete the validation of the data model, readership kits and walkthroughs were used with functional area experts from the ITI-ALC team.

The validations of the "TO-BE" functional and data models were accomplished in conjunction with the validation of the BPIs. As the "TO-BE" functional and data models were developed, readership kits and walkthroughs were used with functional experts from the ITI-ALC team. The BPIs identified from the analysis of the "AS-IS" models and the development of the "TO-BE" models were presented to the Government representatives, functional experts, and users representatives to ensure the accuracy and practicality of the improvements concepts and to expand and refine the BPIs.

The validation of "AS-IS" and "TO-BE" process and simulation models was accomplished, to a great extent, in parallel. As segments of these models were developed, internal walkthroughs were held to ensure the process flows were consistent with the process flow understanding gained during the development of the functional and data models. Walkthroughs of the process flow and simulation models were then held with functional experts from the ALCs and followed by validation trips with users at the ALCs.

The SSS, based on the functional requirements derived from the "TO-BE" functional model, was verified by members of the ITI-ALC team using reviews at various points during its development. When completed, a validation by users from the ALCs was performed using a Joint Application Development (JAD) format. During this two-day workshop, every functional requirement was reviewed by the users, with only a minimal number of minor changes needed.

2.1.2 Traceability Method

The tracing of requirements from the SSS and SSDD back to the user-specified needs ensures that the resulting streamlined depot process and the supporting ITI-ALC system accurately and completely addressed the needs of the users. Requirements traceability may be viewed as a quality assurance method used to ensure the following:

- Requirements are valid, clear, and testable.
- Each requirement has been allocated.
- Each step-in design is capable of satisfying all the allocated requirements.
- No requirements have been inadvertently omitted or "lost."
- No extraneous requirements are introduced.

Requirements traceability also provided a means of requirements validation. For example, a low-level requirement should be traceable to a higher-level "parent" requirement based on decomposition of the parent requirement. If it is not a pure requirement, part of a set of decomposed requirements or a pure derived requirement, then it is an invalid requirement for which there will be no traceability. Traceability includes forward tracing during development forward from the user-specified need to its implementation in the design, and backward from the implementation to the origin of the requirement to provide context for any requirement, thus ensuring a clear understanding of the intent behind the requirement.

Requirements were written in a clear, concise, uniquely identifiable format to facilitate traceability. Compound requirements were avoided unless absolutely necessary and only when those requirements cannot be clearly decomposed for allocation to finite components of the system design.

Figure 2-3 depicts the traceability scheme use for the ITI-ALC program which was supported by the Requirements Traceability Component (RTC). The RTC tool supports multiple users to perform requirements analysis by presenting and organizing data in a way that establishes and maintains relationships between multiple sources of data. The RTC tool supports the development of these relationships, or links, during each phase of the development cycle.

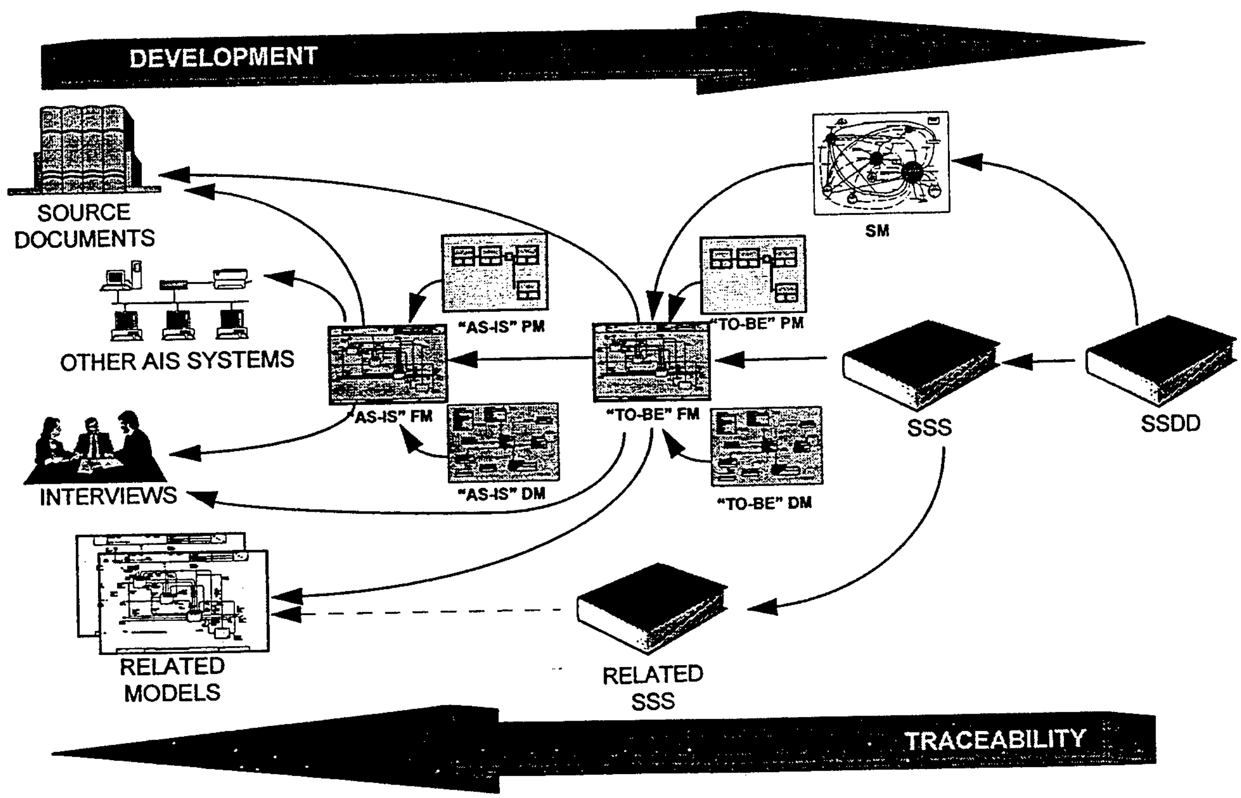


Figure 2-3. The ITI-ALC Requirements Traceability Scheme

Traceability exists for all levels of the "AS-IS" models. *Implicit* traceability to higher-level nodes of the model and *primary, explicit* traceability to the lowest-level of decomposition of each model was established. For the ITI-ALC "AS-IS" models, traceability was established from the model's lowest-level nodes to the:

- Data obtained from the interviews.
- Data regarding other systems with which ITI-ALC must interface.
- Data obtained from source documents.
- Models developed for the IMIS program.

The most important traceability for the "TO-BE" FM was to the "AS-IS" FM. Also, because improvement ideas were also received from the users, related models, and other source documents, there was also traceability from the "TO-BE" FM to these sources. As with the "AS-IS" model tracing, information in both the "TO-BE" DM and "TO-BE" PM traced back to the "TO-BE" FM.

The SSS was developed to contain all requirements applicable to the ITI-ALC system as implied through the "TO-BE" FM. Therefore, traceability of all the requirements stated in the SSS were traced back to the "TO-BE" FM.

The traceability of the SSDD was to both the System Model and the SSS. The System Model established the high-level design of the ITI-ALC system in terms of the "system processes" and interface requirements. The SSDD used the structure of the System Model to specify the components of the ITI-ALC system. Therefore, providing direct traceability from the ITI-ALC SSDD to the System Model. For the SSDD-to-SSS traceability, each Hardware Configuration Item (HWCI), CSCI, and manual operation of the SSDD was traced to the system functions, requirements, and interfaces defined in the SSS.

2.1.3 Tool Selection

The methodology summarized in this section was established to ensure the effective development of the ITI-ALC program. Being effective required that each step builds upon the results of the previous steps and that all work performed had a direct impact on the completeness and quality of the final product, with no wasted time or effort. Furthermore, although less important than the method itself, the correct tool also facilitated effective development.

A set of manual and automated tools facilitated the performance of each step in the methodology as well as the transfer of information among the steps. Table 2-1 identifies the selected tools the methodology step to which they were supplied, and the producers of the tools.

The data collection step was supported by the DCD tool. The DCD was implemented on a portable computer that could easily be taken on the data collection trips and supported the use of other applications such as the IDEF modeling tools, a word processor, and a spreadsheet. The

DCD was designed with the structures necessary to capture all the data that might be identified during the data collection efforts, and with a user interface that allowed for the input and output of information in a manner intuitive to the interviewers and modelers.

Table 2-1. Tools Used to Implement the Methodology

Methodology Step	*Tool*	*Producer*
Data Collection	Data Collection Device (DCD)	SRA Corp.
"AS-IS" and "TO-BE" Functional Modeling	Design/IDEF, Version 3.5	Meta Software
"AS-IS" Data Modeling "TO-BE" Data Modeling	Design/IDEF, Version 3.5 ERWin, Version 2.1	Meta Software Logic Works
"AS-IS" and "TO-BE" Process Modeling "AS-IS" and "TO-BE" Simulation	ProSim, Version 2.0 WITNESS, Version 6.0	KBSI,Inc. AT&T
Site Selection	Expert Choice (8.0)	Expert Choice Inc.
FEA	TurboBPR 2.0	SRA Corp.
SW Cost Estimates	CheckPoint (2.1)	SPR
System Model	System Architecture, Version 3.0 G6A	Popkin Software Systems
Traceability	The Requirements Traceability Component (RTC) of WISARD, Version 2.2	SRA Corp.
Documentation	MicroSoft Word, Version 6.0 and other MicroSoft Office tools	MicroSoft

The functional models and the "AS-IS" data model were supported by the Design/IDEF. The capabilities of the functional modeling aspect of Design/IDEF were well known to the ITI-ALC team and the capability to effectively transfer information from the functional model to the tools supporting other steps within the methodology had already been established and proven. The selection of Design/IDEF to support the development of the "AS-IS" data model was also based on past experience with the tool and the knowledge that the last release of the tool had significantly improved capabilities.

While the capabilities of Design/IDEF to support the "AS-IS" data modeling were adequate, an analysis of the ERWin tool demonstrated that it had key benefits over the data modeling aspects of Design/IDEF. Specifically, ERWin provided improved transfer of attributes among the entities to better support the implementation of the $IDEF_{1X}$ notation. Therefore, ERWin was selected for use in developing the "TO-BE" data model.

ProSim was selected to implement the process flow model because it was the only commercially available tool advertised to support the $IDEF_3$ notation. Similarly, WITNESS was selected to develop the simulation because an automated transfer of information from ProSim to WITNESS that facilitated the development of a simulation model directly from the process flow model was advertised to exist and fully operational.

System Architecture was the tool selected to support the development of the system model. This tool supported a top-down approach to modeling that facilitated the traceability between the "TO-BE" functional and system models, and provided the capability to represent information stores and interfaces within its notation. These capabilities provided an effective means of representing the ITI-ALC system.

Expert Choice (EC), TurboBPR, and CheckPoint were application tools used in some aspect of the development of the ITI-ALC Business Case. Expert Choice was used to select the sites featured in the business case. TurboBPR was used to perform the Functional Economic Analysis (FEA) and CheckPoint is a system/project cost estimation tool used to determine some of the costs with the ITI-ALC system implementantion.

The RTC tool was developed by SRA to support the tracing of requirements throughout the ITI-ALC program to ensure the user needs were completely and accurately represented in the SSS and SSDD. This development was necessary because no COTS tools existed nor did the capability exists within the other tools selected for this project.

MicroSoft Word was used to document all the results of the ITI-ALC program. This application was selected because it accepted the electronic transfer of information from all the other selected tools and facilitated the formatting desired for the various reports. Other applications used throughout the program were MicroSoft Excel and MicroSoft PowerPoint. Refer to Appendix A for details on how the documentation was accomplished.

3. *DISCUSSION AND RESULTS*

The products of this project were a set of artifacts and/or deliverables that documented the knowledge gained during the performance of the ITI-ALC Phase I program. Specifically, the products produced were:

$IDEF_0$ Functional Models (FMs)
"AS-IS" – Represents the current depot maintenance activities.
"TO-BE" – Represents the recommended or future depot maintenance activities.

$IDEF_{1x}$ Data Models (DMs)
"AS-IS" – Represents the logical information structure that supports the current depot maintenance process.
"TO-BE" – Represents the recommended logical information structure to support the future depot maintenance process.

$IDEF_3$ Process Models (PM) & WITNESS Simulations
"AS-IS" – Represents the dynamic aspects of the current depot maintenance activities as defined by the "AS-IS" FM.
"TO-BE" – Represents the dynamic aspects of the recommended or future depot maintenance activities as defined by the "TO-BE" FM.

System Model (SM)
– Represents the ITI-ALC system.

Business Case (BC)
– Documents the cost/benefit analysis for the "TO-BE" implementation.

System/Segment Specification (SSS)
– Documents the requirements for the retool needed in the "TO-BE" implementation.

System/Segment Design Document (SSDD)
– High-level design for the "TO-BE" implementation.

IMIS/ITI-ALC System Comparison
– Functional comparison between the IMIS and ITI-ALC system, and a demonstration plan for the next phase of ITI-ALC.

Demonstration Plan
– Planning document for a Phase II demonstration of the ITI-ALC system.

The following sections present discussions pertaining to each of the artifacts/deliverables developed for this effort as well as possible recommendations and/or specific lessons learned during its development. This list of possible recommendations and/or lessons learned is also repeated in Appendix C, organized by artifact/deliverable.

3.1 "AS-IS" MODELS

A set of "AS-IS" models were developed to provide a complete and accurate representation of the correct PDM process. These model developments were based on information collected from each of the five ALCs by using a systemactic data collection approach. This data collection approach is documented in Appendix D.

Using the collected information, the functional model development was initiated first and followed by the data model development. The development of the "AS-IS" process model was initiated later in the program, following the addition of that requirement to the ITI-ALC program.

3.1.1 "AS-IS" Functional Model

The "AS-IS" FM is a representation of the existing Air Force's depot maintenance process. The purpose of this model is to provide a means of logically illustrating and documenting the functions currently performed within the depot maintenance process along with the informational relationships among the functions. The primary goal of the "AS-IS" FM was to aggregate the process description data collected from the five ALCs into a single representation of a depot maintenance process that highlights duplications and similarities among the ALCs as well as difference among the ALCs. The scope of the ITI-ALC program, and therefore the "AS-IS" FM, is primarily PDM, with a limited look at components and backshop. The viewpoint of this model is that of the maintenance personnel.

3.1.1.1 "AS-IS" FM Development

The strawman model provided the starting point for the development of the "AS-IS" FM. Using the data collected during the data collection trips, the strawman model was refined and expanded into the "AS-IS" FM.

The first step in developing the "AS-IS" FM was to refine the purpose and viewpoint of the strawman model to formalize the scope and content of the information to be included in the model. Establishing an effective purpose and viewpoint for the "AS-IS" FM was very important because it also established the scope and viewpoint for all subsequent models.

Using the strawman model as a reference point, data searches were performed through the DCD to systematically access and organize information. This information was analyzed to support the decomposition of each activity within the strawman and resulted in a complete and accurate description of the depot maintenance process as contained within the scope of the program.

This data retrieval and model development process also identified holes and inconsistencies in the data contained in the DCD. In order to correct these information problems, one or more of the following actions were taken.

1. The original data collected (e.g., notes, tapes, etc.) from the interview(s) was reviewed and compared to the data contained within the DCD.

2. Discussions were held with functional experts available on the ITI-ALC team.

3. Each ALC had an ITI-ALC point-of-contact (POC) on-site who researched or collected more data to resolve information problems.

At intervals during the model development, scenarios were developed and used to present the model to members of the ITI-ALC team. These walkthroughs provided two benefits. First, they provided a communication vehicle to ensure that the collected information was being interpreted correctly; therefore, ensuring that the model was validated within the ITI-ALC team. Second, the walkthroughs provided a means by which the ITI-ALC team could understand and discuss the depot maintenance process. This foundation of understanding was critical for future discussion with depot maintenance personnel and for identifying and evaluating process improvements. This process of data accessing, analysis, modeling, and validation continued until the model was to the level judged necessary to satisfy the requirements of the ITI-ALC program.

Along with each diagram was developed a narrative was described, at a minimum, the primary process flow through the diagram. Additional process flow information was included as appropriate, but the overall narrative was limited to three-fourths of a page due to the page-pair format used to document the model. The joint development of the diagram and the narrative also provided a means of verifying the completeness of information being presented in the diagram.

As each arrow was placed on a diagram and identified, a definition was associated with the arrow. The arrow names and their definitions were then pulled from the model, along with a reference indicating the diagram on which the arrow appeared, to form the glossary for the "AS-IS" FM, which was merged with the "AS-IS" DM glossary.

3.1.1.2 "AS-IS" FM Validation

The review and validation of the "AS-IS" FM was accomplished as an integral part of the model development effort. The review and validation approach was different at the various stages of the model development; however, the underlying purpose for validation was to ensure the model's accuracy and completeness, and to gain user involvement in the models and thereby gain model acceptance and ownership by the users. Following each review and validation, all comments received were documented and analyzed for incorporation into the model.

Throughout the development of the "AS-IS" FM, internal walkthroughs were held among members of the ITI-ALC team, which included functional experts. These walkthroughs were based on scenarios which overlaid onto the functional model. Also, these walkthroughs ensured that information obtained by the team was included in the model and provided a common process understanding among the team members. This common understanding was required for the identification and discussions of the Business Process Improvements (BPIs).

As the model neared completion, 14 interview kits were provided to members of the ITI-ALC team. This cycle was followed by 44 interview kits being sent to ARINC functional experts and depot maintenance personnel located at the ALCs. Finally, six scenario-based walkthroughs were developed and presented to 45 users from four ALCs. The model validations were performed using a method called the "IDEF schematic." In IDEF, a schematic is all of the lowest-level IDEF diagrams connected together to form a complete picture of the activity being modeled. The positive reaction received from these walkthroughs indicated the "AS-IS" FM provided a complete and accurate representation of the PDM portion of depot maintenance.

3.1.1.3 "AS-IS" FM Traceability

The "AS-IS" FM is developed to represent an accurate and complete description of the current depot maintenance process, with a focus on PDM. Since the information used to develop the "AS-IS" FM came from the users at the various depot sites, it was necessary to trace information in the "AS-IS" FM back to the users to ensure that all the user needs were incorporated in the model.

This traceability was accomplished by tracing each activity in the "AS-IS" FM to an interview number, and by ensuring that every activity documented in the DCD was represented in the "AS-IS" FM.

3.1.1.4 "AS-IS" FM Possible Recommendations and Lessons Learned

The following lessons were learned during the data collection, and the development and use of the "AS-IS" FM. Possible recommendations may also apply.

- **Significant preparation for the data collection trips was critical.**

  User acceptance is critical to any system development effort. Because the data collection trips were the first technical interface with the users and because humans have a tendency to let "first impressions be lasting impressions", the data collection trips provided the first and best opportunity to gain the users' acceptance of and involvement in the ITI-ALC program. To acquire the desired positive impression, the data collection trips must be well planned and effectively implemented.

  The data collection for the ITI-ALC program was effective. The strawman model provided a solid baseline for identifying the data to be collected, identifying the sources for the data, providing a good vehicle for training the interviewees about the process, and understanding where each interviewee fit into the depot maintenance process prior to starting an interview.

  The question set provided an effective means for supporting the data collection trips. While used only to a limited extent during the actual interviews, the primary value of the question set was in training the interviewers prior to the data collection trips. Much like the notes developed and used by an orator to prepare and practice the speech but used only as a quick reference during the delivery of the speech, the primary value of the question set was received during the preparation of the data collection effort.

- **Maintain a list of documents collected, user identified problems and improvement ideas, and a list of activities already defined.**

  To implement an effective and efficient interview, each interview should confirm as well as build upon information from previous information. To support this information building process, an up-to-date list of key information should be maintained as reference and to reduce unnecessary effort.

  A valuable source of information are documents, forms, etc. that are used within the process being described. Listing these documents, along with a short description of each provides an effective way of understanding what the interviewee is meaning when he indicates one of these documents and also provides a way of tracking which documents have already been requested or received.

  In a similar manner, maintaining a list of process problems and solutions provided during previous intervals provided a guide to confirm the same ideas from multiple sources and to build upon the ideas presented.

  A list of activities performed within the process was also maintained in the DCD as a point of reference. This list provides a means of learning the terminology, of mapping previous interview information with information currently being collected, and identifying similar functions identified by different terminology. Using this approach produces a controlled but not restricted list of standardized activity identifiers.

- **The data collection interview must be carefully controlled by the interviewer.**

  Interview control must be balanced between strict control where the interviewee is answering very specific questions, and loose control where the interviewee is doing all the talking. Asking questions based very tightly on the question set tended to limit the information provided by the interviewee and assumed that the interviewer's prior understanding of the process was accurate because the interviewer was directing the information being obtained. Initiating the interview with "tell me what you do" does not focus the interviewee so they tend to ramble, hoping they say something that is of importance to the interviewer.

  The most effective approach was to explain our current understanding of the depot maintenance process, describe the types of information desired, and then ask questions that focused the interviewees discussion around the information needed. It was the interviewers responsibility to evaluate the usefulness of the information being provided and determine when additional questions were needed to refocus the discussion to ensure that the data requirement of the question set were satisfied. By allowing the interviewee to describe the process in their terms reduced their need to adjust to an unfamiliar way of discussing their process. As a general rule of thumb, it was effective at 2 to 3 minute intervals to ask a refocusing question or provide some type of indication to the interviewee that appropriate information was being provided.

Scheduling the interview for the one-hour duration was sufficient to collect significant information and not lose the attention of the interviewee. To aid in accurately documenting the collected information, a one-hour period should also be scheduled immediately following the interview to formally record the information while it is still fresh.

- **An end-of-day meeting should be held during data collection trips.**

The data collection teams should meet at the end of each day to review the events of the day and to distribute information among the team members. This review should address the individuals interviewed during the day, a summarization of the information obtained, identification of missing information, and a review of the reference list containing the documents collected, systems and activities identified, and process problems and improvement ideas. The schedule for the next set of interviews should also be reviewed and coordinated to ensure that each interview will be as productive as possible.

- **Allowing analysis time between data collection trips facilitates the collection of accurate and complete data.**

Obtaining accurate and complete data requires that the interviewee and interviewer have the same interpretation of the questions being asked during data collection, that the interviewee is providing accurate information, and that the interviewer is interpreting the answers correctly.

The best way to identify discrepancies in the collected data is to obtain and analyze information related to the same aspect of the process but from different sources. This analysis is facilitated by allowing sufficient time between the interview trips. This analysis verifies the process understanding by the interviewers, verifies consistency among the data, and identifies holes in the data.

- **Effective scoping of the functional model is important to maximize the benefits received from a BPR effort.**

The focal point of the ITI-ALC program was the PDM mechanics within the Air Force's Air Logistics Centers. However, the scope was expanded at program initiation to include within the scope of ITI-ALC's BPR analysis the operational environments impacting the mechanic's performance effectiveness. This expanded scope provided the foundation needed to effectively streamline the mechanic process since much of the work performed by the mechanic was a duplication or continuation of the work performed by other individuals. Therefore, restricting the scope of the ITI-ALC program just to the mechanic would have limit the BPIs identified for the mechanic and would have reduced improved effectiveness provided by the proposed ITI-ALC system.

3.1.2 "AS-IS" Data Model

The "AS-IS" DM is a logical representation for how the data used within the current depot maintenance process is organized and related. The purpose of this model is to provide a tool for analyzing the effectiveness of the logical organization. The "AS-IS" DM representation identifies groupings of data called entities and properties of those entities called attributes.

3.1.2.1 "AS-IS" DM Development

The data for the "AS-IS" DM model was obtained from a number of sources, but the primary data source was the arrows from the "AS-IS" FM. The arrows, representing inputs, outputs, and controls, from the lowest-level nodes of the "AS-IS" FM were selected and separated into three categories: (1) activation triggers, (2) physical items, and (3) pure data.

The physical items are arrows that represent actual tangible items such as an aircraft or an engine that moves between activity nodes. These arrows had to be examined to determine what data about these physical items actually flows through the system. In theory, it is possible that no data may be associated with these arrows, but in practice we found that data was maintained about each of the physical data arrows somewhere within the system. This data was added to the data represented by the data items. In many cases, these data elements represented aggregates of separate facts (properties); therefore, they were further decomposed. The individual facts became the attributes. The attributes were grouped into logical groupings to form the entities.

The development of the "AS-IS" DM was initiated using information represented by the arrows on the strawman model. Then at each point during the model development effort when the "AS-IS" FM was considered baseline, the arrows were collected via the arrow report from the "AS-IS" FM and used to verify, expand, and refine the "AS-IS" DM.

The listing of arrows was grouped into sets of like elements. From these sets, potential entities and attributes were identified, and some of the relationships among entities specified, and additional entities were suggested. Using the notation of $IDEF_{1X}$, this process was aided by trying sample instance tables on the potential entities and relationships to determine whether the modeled business were reasonable. The attributes were then added to further define the entities. As the DM was being developed, information voids and questions were related back to the FM to help enhance the completeness and accuracy of the FM.

Normalization rules were then applied. The many-to-many relationships were resolved through the development of associative entities. However, it was decided that recursive relationships would be allowed unless additional attributes needed to be maintained in a resolving associative entity (i.e., the model would not attempt 5th normal form). We also decided that we would allow for attributes having null values (i.e., the model would not strive for 4th normal form). We did not see any value added by introducing the additional model complexity that the many resolving category entities would produce.

A decision had to be made regarding the handling of the many "non-atomic" data elements that were identified. An atomic (normalized) data element carries only one piece of information. However, in the "AS-IS" world, many common data elements contain multiple pieces of information. For example, the well-used document number contains the Stock Record Account Number (SRAN), the document date, and a serial number. The SRAN itself contains multiple types of data. This could be broken into numerous atomic attributes. However, it was decided that to do so in the "AS-IS" DM would make it more difficult for functional experts to recognize the data and be able to validate the model. Instead, it was decided to leave these types of non-atomic attributes in the model, but to document the elements of information within them in the glossary. This allowed for normalization in the "TO-BE" DM.

If the "AS-IS" FM was decomposed to its lowest possible level and involved no information bundling, each data arrow would represent a single data element that would translate into an attribute. Since this level of decomposition was not necessary and too time consuming for the analysis for which the model was intended, the data bundling necessitated access to additional data sources through which the individual data elements could be identified. These data sources were identified by the mechanisms on the "AS-IS" FM. These sources included individuals performing the maintenance process, documentation describing the process, artifacts from existing AIS, and forms on which carried the information through the depot maintenance process. This process was augmented by using functional experts to explain and elaborate the data found.

To maximize the coordination of the "AS-IS" DM with the FM as well as other program efforts, the wording and the data element descriptions or definitions from the DM glossary were coordinated with the FM. In addition, *The Department of Defense (DoD) Enterprise Model, Volume I: Strategy Activity and Data Models* was referenced to maximize the standardization of terms and definitions with other programs. JLSC's *IFB IDEF$_{1x}$ Model and Glossary (key-based) Technical Report*, 28 February 1994 was also referenced to ensure linkage with the bigger picture of depot maintenance it provides.

3.1.2.2 "AS-IS" DM Validation

The DM validation process was accomplished through walkthroughs with functional area experts, author-readership cycles, and validation trip walkthroughs. The validation addressed two perspectives. First, the reviews ensured that correlation existed between the FM and DM, the DM conformed to the syntax of the modeling language, all terms were fully defined in the glossary, and the correlation with other depot maintenance information was maximized. Second, the validation process ensured the model provided complete, accurate, and understandable logical representation of the depot maintenance current information. After each review, the DM was updated to reflect the comments received.

Because the "AS-IS" FM controlled the baseline information contained in the "AS-IS" DM, the validation of the FM provided a significant step toward the validation of the DM. Additional validation of the DM was accomplished through walkthroughs with functional area experts, author-reader cycles, and validation trip walkthroughs.

It was soon evident that presenting the model as a whole did not facilitate effective review of the model. While the FM is segmented into easily understandable diagrams by its nature as a hierarchical model, the DM does not have this feature. Therefore, the DM was segmented into broad classes of information types called subject areas. The attributes in each entity were examined to evaluate what type of information was represented. Then entities with similar types of information were grouped. By examining the classes of information represented, seven major subject areas emerged: MATERIEL, PLANS, ACTIONS, FACILITIES, LOCATION, ORGANIZATIONS, and PEOPLE. These correspond to seven of the 13 strategic level data "buckets" in the DoD Enterprise Data Model.

The "AS-IS" DM was presented in both presentation and formal documentation using a page-pair format based on the subject areas. The narrative for the subject area was on the top-page and the subject area DM on the bottom page. Included with the page-pair model was a cross-reference chart mapping each entity to the subject area and the glossary containing definitions of all entities and attributes in the model.

3.1.2.3 "AS-IS" DM Traceability

The traceability of the "AS-IS" DM was accomplished by mapping the entities of the DM to the data arrows of the "AS-IS" FM. Because of the bundling of data in the FM arrows, mapping to the attribute level of the DM was determined to be impractical. When an arrow mapped to an attribute that migrated to several entities, such as a foreign key, it was mapped only to the entity that owned the attribute.

The results of the mapping was presented as a matrix so that the DM-to-FM and the FM-to-DM could both be readily seen. This mapping was documented within the RTC.

3.1.2.4 "AS-IS" DM Possible Recommendations and Lessons Learned

The following lessons were learned during the development and use of the "AS-IS" DM and/or may present possible recommendations.

- **Developing the DM in conjunction with the FM resulted in a tight linkage between the models.**

  The original plan expected that modeling the functions performed would uncover many of the data requirements. However, we found that the data modeling also uncovered additional functional requirements. This two-way interchange could take place by walking through scenarios in the FM and identifying the information within the DM that supports the scenarios. Because of the tight linkage between the DM and the FM, the merging of the two glossaries was feasible and more useful than the presentation of individual glossaries.

- **The use of Design/IDEF as the $IDEF_{1X}$ modeling tool required some other conventions be adopted.**

  DoD 8320.1-M-1 mandates that a data element name consists of a prime word name with its modifiers and the generic element name with its modifiers. This convention was not adopted for two reasons. The tool automatically draws the entity boxes large enough to accommodate the largest entity or attribute name. Using fulling qualified names made the diagram much too crowded. Even using only the prime word name had to be relaxed because the tool requires that each attribute within the model be unique. So in some cases, the attribute name was concatenated on the entity name to form a unique attribute name. For example, more than one entity has an identifier attribute. To keep them unique, they became facility-identifier, cost-center-identifier, etc.

- **The data models could not be reviewed effectively as a whole.**

  The data models representing the "AS-IS" and "TO-BE" depot maintenance process were too large and complex to be effectively presented and reviewed as a single, complete model. To facilitate the reviews and and model discussions, the model was divided into subject areas, with each subject area containing groupings of related information. These subject areas were then same enough to support and effective and focused review. In addition, the subject areas also allowed for the use of an effective model documenation format. This format was a page-pair structure consisting of a subject area diagram and the associated text describing the diagram.

- **The normality rules had to be applied in a manner that maximized the development and usefulness of the "AS-IS" DM.**

  A primary objective of data modeling is to describe system data to the level where the data is completely normalized at the atomic level without duplication of null attribute values. While this is an optimal goal to strive for, a trade-off must sometimes be made between the optimal data model and a useful data model. For the ITI-ALC program, this optimized trade-off was defined by the following conditions.

  1. The model would be developed to the 3rd normal form. The 5th normal form was not implemented since recursive relationships would be allowed unless additional attributes needed to be maintained in a resolving associative entity. The 4th normal form was not implemented to allow for the use of null attribute values. This avoided the creation of many category entities needed to eliminate null attributes but decreased the ease of understanding the data contained in the model.

  2. Not all data was broken down to its atomic or normalized data elements. Trying to achieve all the atomic data elements involved significant effort but provided minimal benefit return. Also, representing the atomic data elements would significantly reduce the users' understanding of the model since they do not directly use or reference the atomic data elements.

3.1.3 "AS-IS" PM and Simulation

The "AS-IS" PM was developed as part of the ITI-ALC program for two reasons. First, the process model provided a tool to analyze the performance of the current depot maintenance process. This dynamic view into the current process helped to identify and quantify processing bottlenecks and to help define the performance requirements that must be overlaid onto the functional requirements to fully specify the ITI-ALC system. By providing these added capabilities, the "AS-IS" PM enhanced the ITI-ALC Business Process Reengineering (BPR), supplemented the validation of the ITI-ALC Architecture baseline, and enhanced ITI-ALC system requirements definition. Second, the "AS-IS" PM provided a basis for evaluating the $IDEF_3$ concept, the capabilities of ProSim, the translation from ProSim to a simulation model using WITNESS, and the value-added by using process and simulation modeling within a BPR effort.

To support the intended goals of the program requirements, the $IDEF_3$ technique was applied according to the specifications defined in *Information Integration for Concurrent Engineering (IICE)* $IDEF_3$ *Processing Description Capture Method Report* (AL-TR-1992-0057), dated May 1992.

Because the requirement to include the PM as part of the ITI-ALC program was initiated after most of the FM development was completed, the development of the "AS-IS" and "TO-BE" PMs were developed concurrently, with the "AS-IS" started slightly before the "TO-BE". Therefore, while the discussion of these two models is presented in different sections of the document, the development, validation, and analysis were accomplished jointly.

3.1.3.1 "AS-IS" PM and Simulation Development

The $IDEF_3$ model was developed for the purpose of representing process flow among the activities performed within depot maintenance. Since the "AS-IS" FM identifies the activities performed in the depot maintenance process and the informational relationships among the activities, the "AS-IS" FM was used as the starting point for developing the "AS-IS" PM.

The "AS-IS" PM was developed as a hierarchical decomposition using a one-for-one mapping between the FM and PM activities to produce the PM activity set. Using both the "AS-IS" FM and the "AS-IS" PM, each activity in the activity set was assigned a performance time and branching conditions for each product or output produced by the activity. This process flow information was then overlaid onto the set of activities to form the process flow.

Once the "AS-IS" PM was developed and the performance information documented, the "AS-IS" PM was translated into a simulation model to form the basis for analyzing the operational performance of the current depot maintenance process. This transition from the $IDEF_3$ model into the simulation model was intended to be performed in accordance with the instructions provided by the ProSim and WITNESS tools. However, due to interface problems that were encountered, a significant amount of data manipulation had to be performed to accomplish a basic translation.

3.1.3.2 "AS-IS" PM and Simulation Validation

The validation of the "AS-IS" PM was implemented as a combination of data collection, "AS-IS" PM validation, and simulation model validation. The validation of "AS-IS" PM used a set of workshops to walk the functional experts through the PM network and simulation, requesting them to validate and add performance information as they were able. These functional areas experts consisted first of those within the ITI-ALC team then the ARINC personnel from the ALCs.

In addition to providing model validation, the walkthroughs also trained the ARINC personnel to perform the validation and data collection process with depot maintenance personnel at their respective ALCs. The information received was used to further refined the "AS-IS" PM and simulation model.

Because one of the primary goals of developing the "AS-IS" PM and was to evaluate the effectiveness of $IDEF_3$, as implemented by ProSim, the initial presentation format used for this model was that provided by ProSim. This representation was supplemented with the performance data presented in a table format.

To complete the validation of the "AS-IS" PM and simulation model, visits were made to the Oklahoma City, Warner-Robins, and Sacramento ALCs. During the Oklahoma City trip, the same validation approach was used as with the ARINC's functional area experts. Specifically, both the "AS-IS" PM and the "AS-IS" FM were referenced in discussing the process flow. Unlike the initial validation, however, the results were marginal due to the confusion caused by addressing multiforms of information at one time.

For the Warner-Robins and Sacramento trips, the presentation approach was modified such that only the performance information was discussed in the context provided by a brief explanation of the activities. Using this approach, the validation was completed effectively and the simulation again was accepted as being realistic.

Following these trips, the "AS-IS" PM and simulation models were refined as required.

The "AS-IS" PM was documented using a page-pair format with a diagram being on the lower page and the performance table for the activities on the diagram presented on the upper page.

The presentation of the simulation was accomplished via graphic capability provided through WITNESS. For all personnel, this approach was sufficient for what they needed to feel comfortable with the operational validity of the simulation.

3.1.3.3 "AS-IS" PM and Simulation Traceability

Since the "AS-IS" PM was developed based on the lowest-level activities in the "AS-IS" FM, the traceability was basically a one-for-one correlation between the activities on the two models.

3.1.3.4 "AS-IS" PM and Simulations Possible Recommendations and Lessons Learned

The requirement to use $IDEF_3$ and simulation analysis within the ITI-ALC program was (1) to provide a test case for using the $IDEF_3$ and simulation techniques, and (2) to evaluate and use these performance analysis capabilities to produce improved requirements and specifications for the streamlined depot maintenance process and the ITI-ALC system. With respect to these objectives, the following possible recommendations and/or lessons were learned.

- **Simulation is worth the effort.**

  The concept of applying $IDEF_3$ and WITNESS to a BPR effort provides significant benefits. Using the tools as stated by the $IDEF_3$ specifications and obtaining these benefits in total was a challenge. However, based on this application experience and the specifications for $IDEF_3$ and ProSim specifically, the following is a list of possible recommendations and/or lessons that were learned from developing the "AS-IS" PM and the corresponding simulation.

- **ProSim did not implement the $IDEF_3$ rules completely as they were specified in Information Integration for Concurrent Engineering (IICE) $IDEF_3$ Process Description Capture Method, dated May 1992.**

  The $IDEF_3$ specification identifies five object states available throughout the project. The Entity Description Type is a pooled item in ProSim and can only be set to one type for the entire project. The $IDEF_3$ specification identifies junctions as providing a mechanism to specify the logic of process branching. ProSim junctions expand beyond branching logic and contain much of the functionality required by processes, such as creating objects or passing multiple created objects.

- **The translation from the process description to the simulation was one-directional.**

  The intent of $IDEF_3$, and implemented via ProSim, is to collect process flow and performance information so as to facilitate the development and execution of a simulation model within WITNESS. Following the translation from ProSim to WITNESS, a significant amount of effort is required to adjust and enhance the information in WITNESS before the simulation model is operational and available for verification, validation, and analysis.

  Because of this additional work required within WITNESS, and because the adjustments made in WITNESS can not be transferred back to ProSim, the benefits of the $IDEF_3$/ProSim representation and capabilities are lost once the first translation occurred.

  During the ITI-ALC program, this situation was addressed by maintaining two separate but correlated models. The $IDEF_3$/ProSim representation was maintained for display of the network while the WITNESS model was maintained for exercising the simulation.

- **The process model notation, as represented by ProSim, was not an effective presentation vehicle.**

  The information represented on a process flow network is very limited, reducing its effectiveness as a communication and analysis tool. To read and understand a network requires a labor intensive process of obtaining and integrating information from other sources.

  The readability of an $IDEF_3$ network could be significantly increased if the process flow information could be overlaid onto the network. For example, labels should be placed on the relationship arrows, conditions listed with the branches, and timing and resource requirements placed a process.

  To support the presentation and readability of the $IDEF_3$ process flows for the ITI-ALC program, the functional models and performance data worksheets were used to discuss and validate the process flows. This approach improved the communications, but using just the performance worksheets proved to be the most effective for discussing and validating the process flows.

- **Scenarios, or small snippets of the entire process, help support the presentation of the process, but did not provide the foundation necessary to effectively analyze the performance of the depot maintenance process.**

  The $IDEF_3$ concept, and specifically the ProSim tool, was developed based on the idea that a large process flow could be developed and analyzed as small scenarios or snippets of the entire process. These small scenarios, consisting of five to ten processes, could then be presented on a single page.

  This segmented approach, however, limits the capability to evaluate the impacts caused by changes across the entire process flow. Evaluating the entire process as a unit was especially important when trying to identify operational bottle necks when parameters in one segment was changed.

- **The data collection for the "AS-IS" PM and the simulation would have been approached differently if this modeling and analysis requirement had been established at the beginning of the ITI-ALC program.**

  The performance information required to develop the "AS-IS" PM would have been collected as part of the data collection for the "AS-IS" FM.

3.2 "TO-BE" MODELS

Through the analysis of the "AS-IS" models, process improvement concepts were developed. To provide the foundation for representing and evaluating these improvement concepts, a set of "TO-BE" models was developed and refined. These "TO-BE" models include the functional, data, and process/simulation. In addition, the System Model (SM) which represents a concept for the ITI-ALC system, is also a "TO-BE" model and will be discussed in Section 4.4 of this document.

3.2.1 "TO-BE" Functional Model

The "TO-BE" FM represents an improved, future view of the Air Force's aircraft PDM process based on the integration of all the process improvement ideas identified thus far. Once complete, the "AS-IS" FM provided the foundation for translating the various aspects of the "TO-BE" concept into the "TO-BE" DM and "TO-BE" PM, and also the foundation for generating the list of ITI-ALC system requirements used in the development of the SSS. The "TO-BE" FM also provided the foundation for developing the functional requirements needed to identify and evaluate the potential technologies for implementing the "TO-BE" depot maintenance process.

3.2.1.1 "TO-BE" FM Development

The first step was to review the "AS-IS" FM purpose and viewpoint to ensure the user remained the focal point for the program. The "TO-BE" FM viewpoint was developed so as not to restrict any implementation concepts and be flexible enough to allow for the inclusion of functions needed for the future view of depot maintenance. During the development of the "TO-BE" model all restrictions were removed that were related to implementation limitations based on existing policies and rules and technology limitations, while the incorporation of innovative ideas and removing the "this is the way it has always been done" attitude were encouraged.

The "TO-BE" FM development was performed as a top-down and a bottom-up analysis of the "AS-IS" model, based to a great extent on the arrow patterns of the "AS-IS" model. The top-down approach was used to understand the context of the entire system as well as that for each activity. The bottom-up analysis allowed for the identification of specific, focused problems identified through the analysis of each activity, and which, through use of impact analysis on other functions, the larger problem and possible cause of the problem.

To these improvement opportunities were added the problems and improvement suggestions provided by the ITI-ALC team's functional experts and users at the ALCs, the data improvement opportunities identified from the "AS-IS" DM, and the process performance problem areas identified via the "AS-IS" PM. The information provided by functional experts and users was often based on situations and corrections that individuals implemented to circumvent problems they encountered with the depot maintenance process. While this information provided significant insight into the process, the ideas had to be analyzed to determine how they should best be represented in the "TO-BE" FM. Specifically, the problems had to be analyzed to determine if they were indeed problems or if they were symptoms of other problems. Similarly, improvement ideas had to be analyzed to ensure they were correcting a real problem or a symptom, and if the inclusion of the improvement would have a detrimental impact on other aspects of the process. As interfacing information systems were identified, they were identified as mechanism for those functions requiring the interfacing.

In conjunction with the development of the "TO-BE" FM, the BPIs being incorporated into the "TO-BE" FM were specifically identified and listed, with a short narrative generated for each.

3.2.1.2 "TO-BE" FM Validation

Because the "TO-BE" FM represented a vision for an improved, streamlined depot maintenance process that will be implemented in the future, there was no conclusive way to validate the process represented by the "TO-BE" FM. However, the "TO-BE" FM was validated to the extent that all members of the ITI-ALC team, and especially the functional experts and users, accepted the "TO-BE" concept because they believed the model to represent a practical and beneficial concept for PDM. Therefore, the validation of the "TO-BE" FM was implemented to provide the functional experts and users with a complete understanding of the "TO-BE" process concept and to gain their acceptance of the improved process.

Based on these objectives, the validation of the "TO-BE" FM was performed by developing a set of scenarios through the model that specifically addressed the BPIs. Using these scenarios, walkthroughs of the model were presented to members of the ITI-ALC team, followed by discussion of the BPIs. Following the internal validations, the refined information was presented to ARINC personnel from the ALCs, but with increased emphasis on the BPIs rather that the "TO-BE" FM. Finally, the BPIs were presented to the users from the ALCs. Following each validation step, the comments received were used to refine the "TO-BE" FM.

3.2.1.3 "TO-BE" FM Traceability

The primary traceability for the "TO-BE" FM was back to the "AS-IS" FM. This traceability ensured that each activity in the "AS-IS" FM was accounted for in the "TO-BE" FM, either in terms of being included, identified as not being included because it was a non-value-added activity and therefore not included in the "TO-BE" FM, or identified as a new activity within the "TO-BE" FM.

3.2.1.4 "TO-BE FM Possible Recommendations and Lessons Learned

The following possible recommendations and/or lessons were learned during the development and use of the "TO-BE" FM.

- **Effective scoping of the functional model is important to maximize the benefits received from a BPR effort.**

  The focal point of the ITI-ALC program was the PDM mechanics within the Air Force's Air Logistics Centers. However, the scope was expanded at program initiation to include within the scope of ITI-ALC's BPR analysis the operational environments impacting the mechanic's performance effectiveness. This expanded scope provided the foundation needed to effectively streamline the mechanic process since much of the work performed by the mechanic was a duplication or continuation of the work performed by other individuals. Therefore, restricting the scope of the ITI-ALC program just to the mechanic would have limit the BPIs identified for the mechanic and would have reduced improved effectiveness provided by the proposed ITI-ALC system.

- **By including the cursory look at the engine and component environments allowed for the understanding for how the ITI-ALC system could aid the entire depot maintenance process.**

  While the focus of the ITI-ALC program was the PDM mechanic, the basic activities performed by all personnel throughout the depot have much in common and are tightly integrated. Making the minimal effort required to understand a larger perspective of the depot operations in terms of the commonality and integration provided the ITI-ALC team with the necessary background to maximize the benefits received from the improved depot maintenance process and the implementation of the ITI-ALC system. Therefore, using this broader perspective assured that the improvement concepts addressed all common aspects and assured that recommended improvements did not negatively impact other processes and personnel involved in depot maintenance.

3.2.2 "TO-BE" Data Model

The "TO-BE" DM defined the maintenance information requirements needed to support the ITI-ALC system and established the foundation for implementing the physical database.

3.2.2.1 "TO-BE" DM Development

The "TO-BE" DM was developing using the "AS-IS" DM and the information specified on the interfaces of the "TO-BE" FM. The "AS-IS" structure was then adjusted and refined to reflect the information represented on the "TO-BE" FM and the BPI concepts that had been identified. One of the key differences in the approach taken by the "TO-BE" DM versus the "AS-IS" DM was to represent an information system that may hold data pertaining to more than one end-item and to more than one ALC without duplication of data. Current systems tend to segregate data by weapon system and ALC. The creation of data structures that were sufficiently complex to represent these interrelationships among the data and the addition of the technical information represented by the IETMs expanded the size of the "TO-BE" DM as compared to the "AS-IS" DM.

The availability of specific information about future data systems and the details of data interfaces for systems currently under development, such as DMMIS, was limited. Therefore, the details that were delineated for the data interfaces between the ITI-ALC system and these types of systems were limited. As these systems are developed and documentation generated, the interface and internal data structure definition can be evaluated relative to the ITI-ALC system implementation.

3.2.2.2 "TO-BE" DM Validation

The "TO-BE" DM was validated in two ways. The first validation step was based on its close relationship with the validated "TO-BE" FM. The information for the "TO-BE" DM was obtained from the validated "TO-BE" FM. Therefore, by tracing the information identified in the data model to the functional model, the content of the data model was validated. The second validation step was accomplished by walking through the subject areas with members of the ITI-ALC team and subject matter experts. Because the "TO-BE" DM represented a projected rather than an existing maintenance environment, the second validation step was based on a consensus by subject experts that all data needed to perform depot maintenance, including that needed to implement the BPIs, were specified.

The "TO-BE" DM was documented within the Architecture Report. To facilitate the documentation, the model was separated into subject areas, each of which addressed a specific aspect of the data within the model. These subject areas were Materiel, Plan, Technical Information, Action, Facility, Location, Organization, and Person. Larger subject areas were further subdivided into sub-subject areas. An entity versus subject area matrix was developed to aid in identifying the subject areas in which each entity was located.

Within the Architecture Report, the "TO-BE" DM was presented at two levels of detail. To provide a overview of the "TO-BE" DM, the entire Entity Relationship Diagram (ERD) was presented as a unit. To provide more detail and usability, the ERDs for each subject areas were presented along with their narratives using a page-pair format. A glossary of definitions for the entities and attributes was developed and documented in combination with the "TO-BE" FM model glossary.

3.2.2.3 "TO-BE" DM Traceability

The traceability of the "TO-BE" DM was developed back to "TO-BE" FM. This traceability consisted of mapping the entities in the "TO-BE" DM to the arrows associated with the lowest-level nodes containing the information within the "TO-BE" FM. This tracing was documented in the RTC.

3.2.2.4 "TO-BE" DM Possible Recommendations and Lessons Learned

The following possible recommendations and/or lessons were learned during the development and use of the "TO-BE" DM.

- **The ERWin tool had significant limitations with respect to producing quality looking documentation.**

  Models are developed for use as analysis tools, therefore, they must be documented and presented in a manner that facilitates the analysis process. While the ERWin tool facilitated the development by controlling the migration of attributes among the entities, the tool did not allow for user control of the relationship layout among the entities. This resulted in data model that was difficult and time consuming to read and analyze. To correct this situation, the completed ERWin model was exported to the Design/IDEF tool which allowed the developer to rearrange the entities and relationships so as to maximize the readability and usefulness of the model.

3.2.3 "TO-BE" PM and Simulation

The "TO-BE" PM and simulation were developed to analyze the operational or dynamic aspects the "TO-BE" depot maintenance process as represented in the "TO-BE" FM concept. Through the operational perspective, the "TO-BE" process flow concepts were evaluated, the processing times were optimized to maximize the efficiency of the process, the performance specifications for the resources were established, the predicted improvement potential from the "AS-IS" to the "TO-BE" environment was estimated, and the support structure was established for performing the performance-technology cost trade-off analysis.

3.2.3.1 "TO-BE" PM and Simulation Development

The development of the "TO-BE" PM was based primarily on the structure of the "TO-BE" FM. This translation of information was obtained by establishing a one-for-one correlation of the activities from the functional model to the process model. The process flow among the activities was established by analyzing the interface relationships between the functional model activities and using the same scenarios developed for the "AS-IS" PM. These scenarios included three small scenarios directed at the mechanic and the planner and a larger scenario directed at the mechanics performing their complete PDM process. By developing corresponding scenarios between the "AS-IS" and "TO-BE" process definitions, the baseline was established for predicting the benefits received from implementing the improved depot maintenance process.

Throughout the development of the process flows, a close working relationship was established among the PM/simulation developers, the ITI-ALC team's functional expert, the business case developer, and the "TO-BE" FM developer. When reasonably stable, the "TO-BE" PM and the "TO-BE" FM were used as guidelines for developing the performance timing for each of the activities in the process model network. This performance time was predicted based on corresponding times within the "AS-IS" PM, on the expertise of functional experts, and on the performance capabilities of technologies.

When the "TO-BE" PM was completed, it was translated into the "TO-BE" simulation model. While the "AS-IS" PM described the flow of information and material through the depot maintenance process, it provided only limited insight in the actual operation of the "TO-BE" depot maintenance process. The "TO-BE" simulation model provided the capability to predict the operational characteristics of the "TO-BE" depot maintenance process. The simulation model was developed by combining the performance characteristics with the "TO-BE" PM. The simulation model was then exercised to evaluate the effectiveness of the proposed process improvements.

3.2.3.2 "TO-BE" PM and Simulation Validation

Due to the late time frame in which the PM effort was performed, the validation of the "AS-IS" and "TO-BE" PMs were performed concurrently. The validation involved a two level process. The materials used to accomplish the validation were the "TO-BE" PM, "TO-BE" process simulation model, the performance information for each of the activities, and the "TO-BE" FM.

The first level of validation was performed by the ARINC functional experts from each of the ALCs. During these reviews, the process models were used by subject matter experts as the basis to discuss the "TO-BE" process flow and the associated performance information. The simulation models were also demonstrated to show that the individual task times integrated to produce the major flow days they were a custom to seeing.

The second level of validation was performed using the same approach at the Oklahoma City ALC. The benefits received from this validation were viewed as minimal. To adjust for the next validations at Warner-Robins and Sacramento ALCs, the validation process was modified so as to discuss only the performance information and to demonstrate the simulation model, without presenting or discussing the "TO-BE" PM network. This approach was viewed as being effective and successful.

For documentation within the Architecture Report, the complete process flow model was too large to present effectively as a single item. Therefore, the model was segmented to reflect the decomposition of activities represented in the "TO-BE" FM. Each diagram was documented in page-pair format with the corresponding page containing the link back to the "TO-BE" FM, the activity name, a short activity description, the resources performing activity, and the products produced by each activity.

3.2.3.3 "TO-BE" PM and Simulation Traceability

Documented in the "TO-BE" PM page-pair format, the "TO-BE" PM was traceable back to the "TO-BE" FM, using basically a one-for-one correlation between the activities in the two model. This tight correlation exists because of the manner in which the "TO-BE" PM was developed from the "TO-BE" FM.

3.2.3.4 "TO-BE" PM and Simulation Possible Recommendations and Lessons Learned

Because the developments of the "AS-IS" and "TO-BE" PMs and simulations were performed to a great extent in parallel, the possible recommendations and lessons learned for the "TO-BE" development are the same as those listed in the "AS-IS" PM section of this report.

3.3 SYSTEM MODEL (SM)

The SM represented an operational concept for the ITI-ALC system and provided the transition from the "TO-BE" functional, data, process, and simulation models to the high-level design documented in the SSDD. In defining this operational concept, the SM identified the system hierarchy, Computer Software Configuration Item-to-Computer Software Configuration Item (CSCI-to-CSCI) interfaces, internal CSCI interfaces, external interfaces, and inputs and outputs of each process. As represented in Figure 3-1, the SM was used to directly develop system design sections which are the major and most important components of the SSDD.

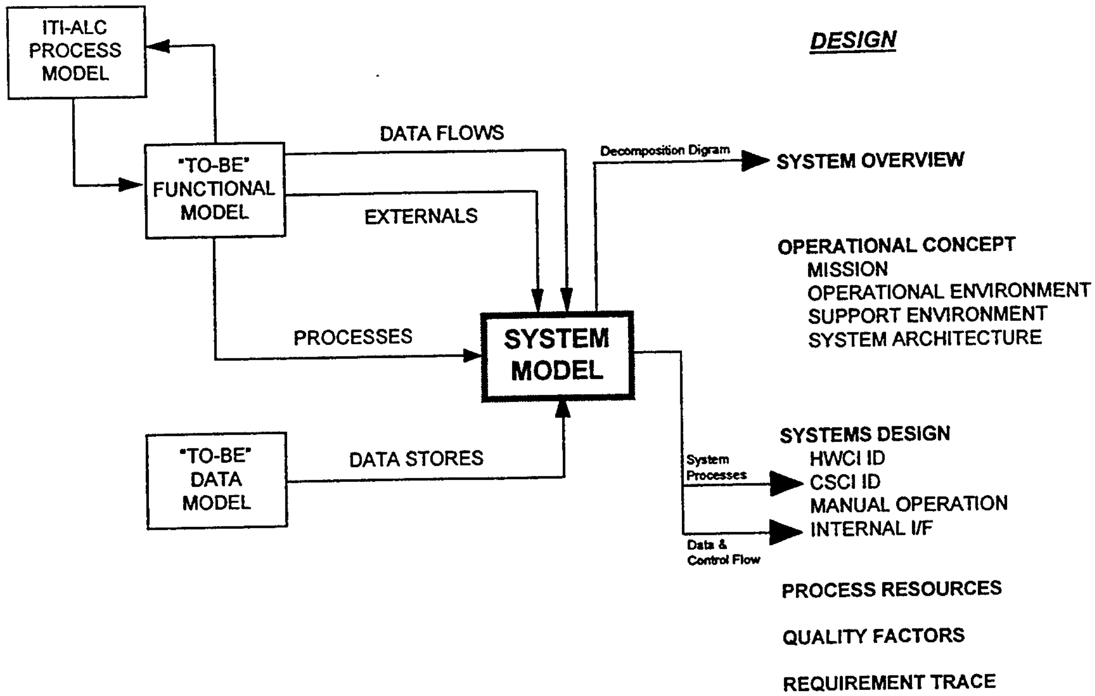


Figure 3-1. Overall Relationship of Three Architecture Models to the Design of the ITI-ALC System

3.3.1 SM Development

A data flow diagramming methodology was selected to represent the SM because of the need for a graphic language to represent information (data) as it circulates (flows) and is transformed throughout a system. The graphics flow provided the users and developers with an effective means of understanding and evaluating complex system requirements in a simple and accurate language. The graphics flow representation did not include any implementation concepts, thereby not forcing any implementation decisions.

As represented in Figure 3-2, analysis of the various operational scenarios and the grouping of functions and capabilities required to operate within those scenarios were used to define modes or high-level structure of the ITI-ALC system as represented in the SM. Having formed this high level structure, the "TO-BE" functional and data models were analyzed to develop an understanding of the operational requirements of the ITI-ALC system.

The "TO-BE" FM defined the activities to be performed within the ITI-ALC system, and the functional interface requirements with both the users of the ITI-ALC system and the information systems external to the ITI-ALC system. The "TO-BE" DM defined the relationships or business rules among the data elements and the data stores that will be maintained within the ITI-ALC system and will require an interfacing capability. Data stores are defined as an aggregate of data the system must "remember" for a period of time. When the system is fully implemented, these data stores will typically exist as files or databases.

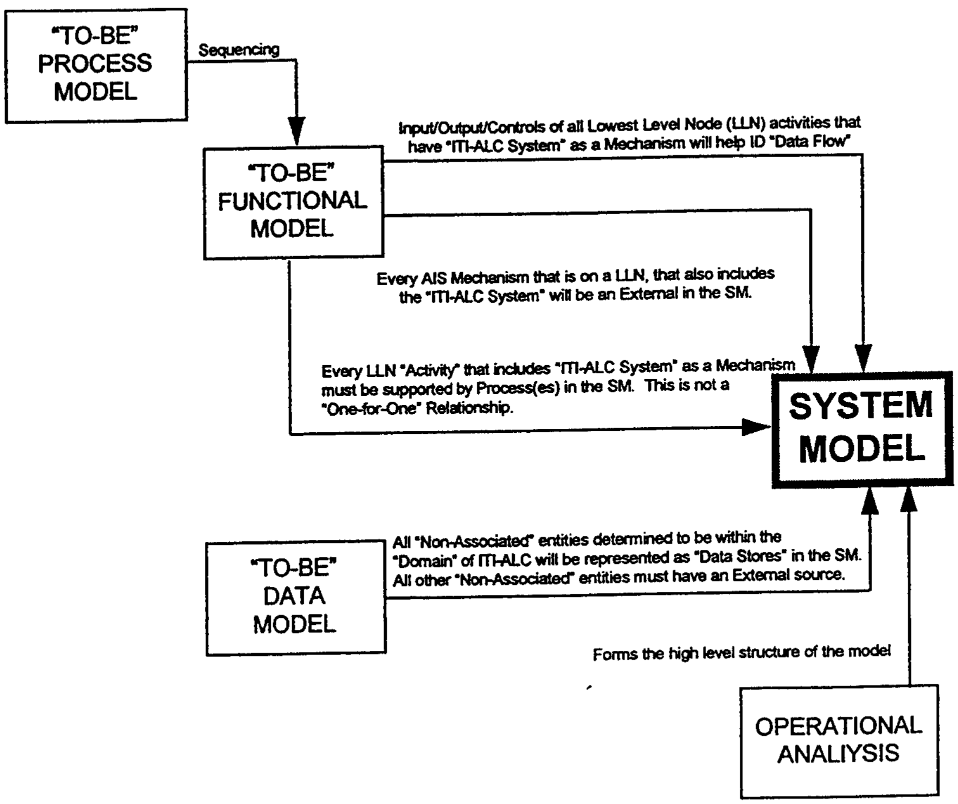


Figure 3-2. FM/DM-to-SM Translation

The SM was developed using a top-down hierarchical approach that corresponded to the structure of the "TO-BE" FM. The highest level diagram contained one function that represented the SM along with a general description of the interfaces with external information system and with the user. On subsequent diagrams, each function was detailed out for these interfaces along with the inclusion of the interfaces to the internal data stores identified through the "TO-BE" DM.

Included in the transition from the "TO-BE" FM and "TO-BE" DM was the elimination of organizational and functional redundancies, and the addition of system-level functions and data to support the operational functions. **Organizational redundancies** result when the same function is performed at two different levels of maintenance. Although, from an end-user perspective these two processes are done at different times, a system that would support these two maintenance tasks would need only one software process to handle both. **Functional redundancies** are very similar to organizational redundancies and a common process that could support all of the common functionality, regardless of where it is performed within the depot maintenance process. **Adding system-level functions and data** to support operational functions is done by determining what ITI-ALC computer system functions will be performed to support the reduced set of FM functions that resulted from the above elimination of redundancy. Items such as display, input, and output from the SM are added to the list of functions to be performed as part of the system capabilities.

3.3.2 SM Validation

The SM validation process ensured the SM provided a complete and accurate representation of the ITI-ALC system. Because the "TO-BE" FM controls the baseline processes that must be supported by the system represented by the SM, the validation of the FM provided a significant step toward the validation of the SM. Beyond this indirect validation, the complete validation of the SM was performed as a two step process consisting of a review process involving the ITI-ALC team which included functional experts and a validation process involving the users. Following each step in the validation, the model was updated based on an analysis of the comments received. The SM review process was addressed from two perspectives. First, the review ensured (1) correlation between the SM and the "TO-BE" versions of the FM and DM, (2) confirmation between the SM and the syntax of the modeling language, (3) completion of the glossary, and (4) maximized correlation with other depot maintenance information. Second, the review ensured the model provided an understandable representation such that an effective validation process could be performed.

The review process included two walkthroughs and one peer review, both involving internal functional experts and systems/software engineers. The first walkthrough oriented the team to the modeling technique, provided an overview concept of the model structure and the operational concept represented via the model, and ensured that the SM addressed the functional and data requirements represented in the "TO-BE" functional and data models

The walkthrough was followed by one peer review conducted as a desk top review. The peer review, which included functional experts, provided ample time for each reviewer to fully review and analyze the model. This review ensured that the SM was usable, as well as comprehensive and compliant with project needs. It also provided early visibility into the status and quality of the product, with ample time to take corrective action if progress and quality are not at acceptable levels.

Finally, the SM was validated with users by using a walkthrough approach This review ensured that the operational concept represented by the SM accurately and completed addressed the operational requirements of depot maintenance personnel.

The SM was documented using a pair-pair format accompanied by a node list and a glossary. The node list was an indentured list of each activity contained in the model. The diagram portion of the model was presented in a page-pair format with a diagram presented on the lower page and a narrative describing the information and control flow represented on the diagram. The glossary contained a name for each interface identified in the SM, a definition for the interface, and a reference to the diagram on which the interface appeared.

3.3.3 SM Traceability

The traceability of the SM was to the "TO-BE" FM to ensure that each function in the "TO-BE" FM identified and performed at least in part by the ITI-ALC system was addressed in the SM. This traceability was a mapping between the lowest-level process in the SM and the lowest-level functions in the "TO-BE" FM. The validation of the linkage between these models was facilitated by the tracing capability provided by the RTC.

3.3.4 SM Possible Recommendations and Lessons Learned

During the development of the SM model, the following were possible recommendations or lessons learned that were identified.

- **Data flow diagrams are an excellent way to represent the system model.**

  The goal of the system model is to provide a transition from the functional and data requirements identified via the functional and data models to the design of the system that will satisfy those requirements. Using data flow diagrams provided an effective way of presenting this transition.

  The data flow diagrams supported a top-down approach and provided a leveling of information that reduced the complexity of information on any one diagram while allowing for increasingly more detailed information on decomposed diagrams. This top-down approach corresponded to that used to developed the functional model, resulting in a strong correlation between the "TO-BE" functional model and the system model.

  The data flow diagrams accommodated the specification of data stores and the interfaces with the data stores. The definition of these data stores provided an effective link to the entities specified within the "TO-BE" data model.

  The data flow diagrams accommodated the incorporation of system control activities and the specification of control flows among the activities and the interfaces to the user, the internal data stores, and the external database systems. Furthermore, a side benefit of this operate is that superior cost estimates based on Function Points can be derived from the models.

- **Although DFDs are an excellent way to represent the system model, the full benefit of the model can not be realized by those not knowledgeable in the model language.**

  Non-native languages have advantages over a native language because they are developed to efficiently present specific types of information. Native languages, on the other hand, have the advantage in that they are common and understood by a majority of people, even though they may not present the information as efficiently and accurately. This language difference causes some problems because the model developers prefer the non-native languages while system users often prefer the native languages. To maximize the benefit of these two perspectives, a two step approach should be used that enhances the communications between the two situation. First, users must be motivated and willing to take the effort to gain a reasonable understanding of the non-native language in order to fully appreciate the information contained in the model and to fully utilize the model. Second, the developers must be motivated and willing to supplement the non-native language with an ICON level abstraction to facilitate the understanding by the users. Development of a common understanding and effective communication maximizes the effectiveness and usefulness of the information produced.

3.4 BUSINESS CASE (BC) CDRL SEQUENCE A002

The ITI-ALC Business Case, an example of a Functional Economic Analysis (FEA), documented predictions of the cost benefits that would be realized from the implementation of the improved depot maintenance process and the ITI-ALC system at the ALCs.

The project approach included requirements determination, system engineering, and business case development as illustrated in Figure 3-3. The methodologies employed were consistent with the Department of Defense's *Framework for Managing Process Improvement* as discussed in DoD 8020.1-M, *Functional Process Improvement*. The economic analysis components of the approach followed the direction in the DoD Corporation Information Management (CIM) *Functional Economic Analysis Guidebook* (January 1993) and the requirements from the Office of Assistant Secretary of Defense's (OSD) *Guide for Developing AIS Cost and Operational Effectiveness Analyses* (OSD, June 1994).

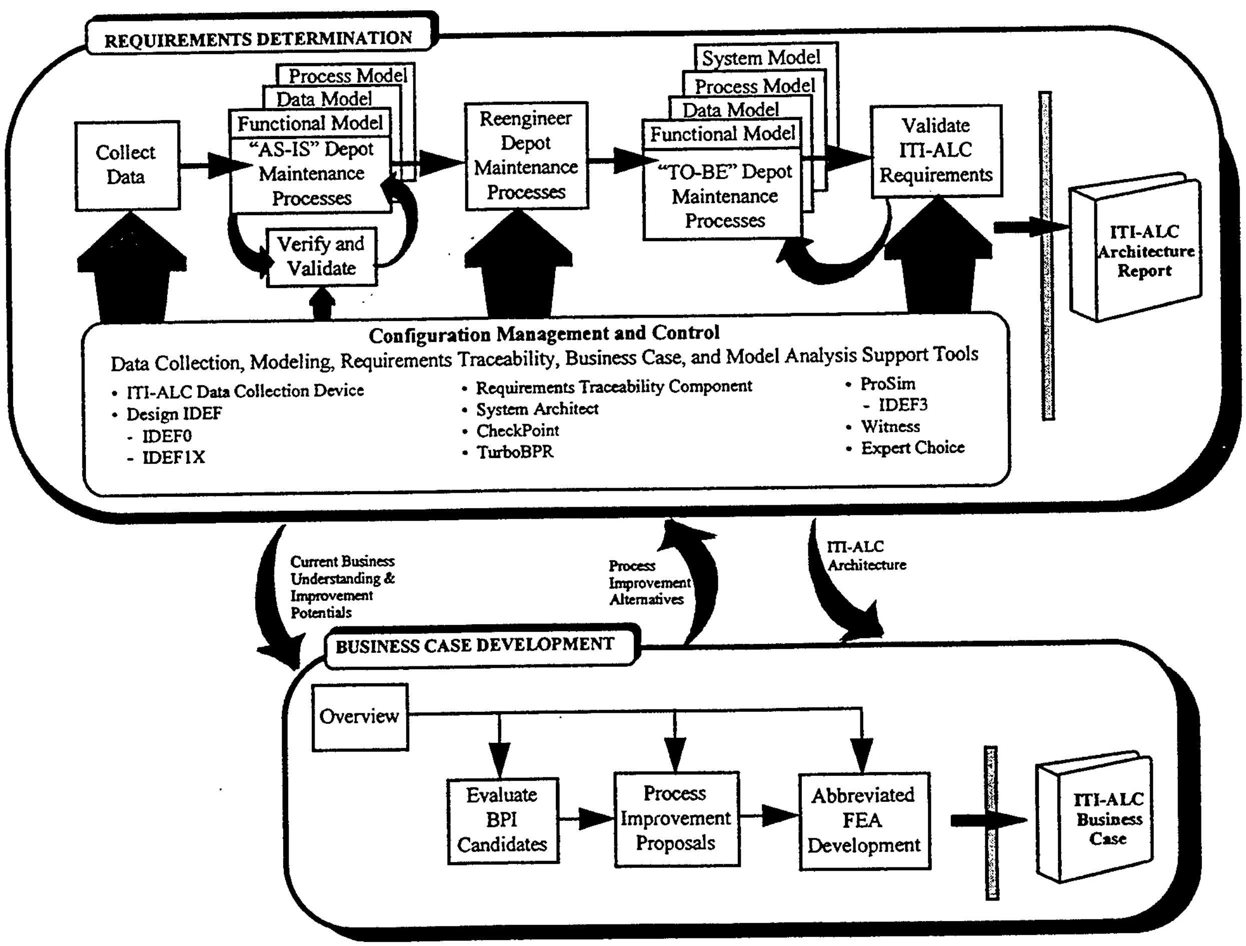


Figure 3-3. ITI-ALC Approach to Business Case Development

The business case required a number of individual steps be performed, the results of which were integrated as part of the business case development. These steps included definition of the improvement proposals, selection of the ALC site to provide the basis for the business case, collection of the cost for the technologies needed to implement the improvements, collection of the cost information for the selected site, and the development of the business case.

3.4.1 BC Development

Like all of the other efforts on the ITI-ALC project, development of the Business Case document was focused on the user, therefore the effort started with data collection. To initiate the data collection effort, the ITI-ALC team reviewed the AFMC and depot maintenance mission, objectives, and strategy. Pertinent Air Force, AFMC, and DoD planning documents were reviewed and interviews conducted at each of the five ALCs to identify function and information relationships. During data collection at the select sites, SM-ALC and WR-ALC, (refer to Section 1.4.2) manpower and cost information was obtained through the financial management and production directorates. The team then associated resource consumption with each activity in the "AS-IS" Functional Model resulting in an activity-based cost functional model to the lowest-level.

To facilitate the implementation of the improvements identified through the ITI-ALC program and to begin realizing early-on benefits from implementing the improvements, the business case was developed around a set of incremental implementation concepts. Based on knowledge of the depot maintenance process, the ITI-ALC team logically grouped slices from each BPI into "packages" called Process Improvement Proposals (PIPs).

These PIPs offer a range of BPI potentials, with each PIP offering some advantage over the current process, and with each PIP implementation building upon the previous PIP implementation that would enable ALCs to move toward or achieve their targets. Table 3-1 summarizes these PIPs.

The PIPs offer a range of improvement, and each PIP offers some advantage over the PDM process as it currently exists. However, the impact should be measured against the objectives of substantially reducing organic aircraft PDM operating expense and flow days. PIP D offers the greatest ability to achieve those objectives. PIP A offers the lesser ability to achieve those objectives.

To provide a basis for selecting the criteria used to measure the cost improvement provided by the PIPs within the business case, a memorandum dated September 15, 1994 by the Secretary of Defense was referenced. In this memorandum the Secretary challenged the Army, Navy, Air Force, Marine Corps, and the Defense Logistics Agency to reduce the business process cycle times by at least 50% by the year 2000. Using this target, as well as information and ideas provided by ALC personnel and PDM customers, two objectives of reducing organic aircraft PDM *operating expenses* and *flow days* were developed as the measurement criteria for the ITI-ALC program business case.

Table 3-1. PIP Summary

PIP	*Description*
PIP A (Process Improvements Only, No ITI-ALC Technology)	Implements a slice from BPIs within the current "AS-IS" paradigm that can begin now, demonstrate the new activity, and is more effective and efficient, though it does *not* include ITI-ALC system technology.
PIP B (Introductory System)	Implements a slice from BPIs within the current "AS-IS" paradigm that produces more improvements in effectiveness and efficiency than PIP A. Some ITI-ALC system technology is introduced to provide on-line access to individual databases and a single interface to core depot maintenance systems. This PIP does not integrate data. Technical data is not organized in IETM format. This PIP can move the PDM process closest to the performance targets without requiring policy changes outside of the maintenance process.
PIP C (Integrated Data)	Implements a slice from BPIs that provides integrated information, introduces IETM data, incorporates more portable ITI-ALC system technology, establishes the infrastructure for Organizational level (O-level) to Depot level (D-level) information sharing, and allows a major breakout of the current process and a major breakthrough in the way the customer is served. Saves more by enabling the reallocation of resources to the direct maintenance effort. This PIP requires a paradigm stretch.
PIP D (Fully Developed ITI-ALC System)	Implements a slice from BPIs that incorporates full ITI-ALC system technology, integrates all the required systems for depot maintenance functionality, provides artificially intelligent tools to support all the BPIs, produces information as a by-product of the work effort, and enables the final step toward achieving the objectives. This PIP will require a major paradigm shift.

For each PIP, the investment cost and potential benefit for these two criteria were evaluated from two perspectives -- that of the maintenance cost to the depot and that of the cost to the customer. One of the most important aspects of this development was selecting the site for the evaluation.

The site selection process was aimed at selecting the most desirable ALC to be used as the basis for developing the business case and for demonstrating the ITI-ALC capability during Phase II of the ITI-ALC program. The final recommendation for site selection will be made jointly by the Government program manager (AL/HRGO), functional/domain experts, and system/software engineers.

The site selection process was accomplished through the application of the Analytic Hierarchy Process (AHP) methodology, based on work done by Herbert Simon. The steps in that methodology were applied using a tool called Expert Choice. The steps were as follows:

1. Problem Definition and Research
2. Elimination of unfeasible Alternatives (low pass filter)
3. Evaluate Candidates
    - Determine Selection Criteria
    - Prioritize/Weight Criteria
    - Make Comparisons (score alternatives)
    - Synthesize Judgment (Expert Choice)
    - Examine & Verify Results (sensitivity analysis, etc.)
4. Document the Decision

These steps were conducted by members of the ITI-ALC team along with individuals from HRGO. A draft set of criteria was developed, and reviewed and ranked by the team members. The individual team members used the criteria to rank each of the ALCs. These rankings were entered into the EC tool to provide a preliminary look at the results. Using the results of the previous steps, two workshops were held during which the previous results were presented, discussed, and adjusted to obtain a team consensus.

Figure 3-4 shows the results of that effort. The graph indicates the score of each of the ALCs. WR-ALC and SM-ALC scores indicate no significant difference using the criteria and approach outlined above. SM-ALC was identified by the DoD as a "privitization" location subsequent to the recommendations of the Commission as Base Closure and Realignment. As a result, the recommended selected site for the demonstration of the ITI-ALC system was WR-ALC. The BC includes benefit-cost analysis for both of these sites.

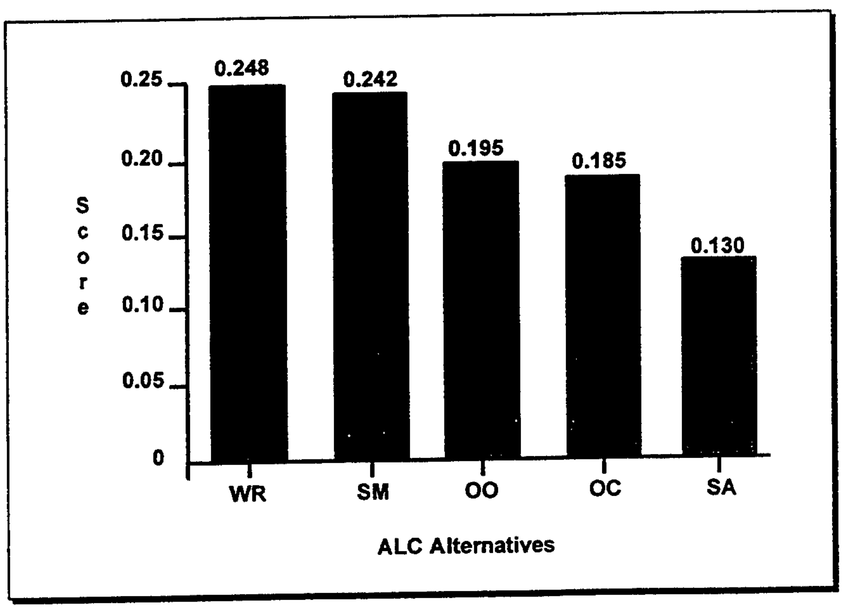


Figure 3-4. Results of the Site Selection Process

3.4.2 BC Validation

An operations research technique was used to test the validity of the cost and benefit estimation results of the FEA. The technique used was a "two-way-blind test." The intent was to have two separate teams, with no association/interaction, and using two different approaches, derive results that could then be compared. Ideally, if the results from the two different approaches were similar, this would indicate the results represented a "real-world" view of the PDM and could be considered valid. Also, if there was a "small" delta between the two results, the delta became a good way to define the confidence interval for the results (although this approach to defining the confidence interval obtains only a locally optimized outcome). The two approaches were Engineering Assessments and Simulations. Very early on in the project, it was apparent that we did not have the resources to conduct a full two-way blind test, so some key members such as a cost analyst and a subject matter expert were on both teams. This provided a measure of control without having a full control group (a third redundant team). Refer to Section 4.4.4, Possible Recommendations and Lessons Learned for suggested solution to this problem.

Furthermore, because simulations are a repeatable experiments, "real-world" historical data could be input into the simulations and compared to "real-world" historical results to calibrate the simulations. Then the simulation engines were used to interpolate results given the changes identified in the BPIs and PIPs. This along with two-way-blind testing allows greater confidence in the results.

3.4.2.1 Engineering Assessments

The next step in the analysis of the depot maintenance processes represented in the static models was to perform engineering assessments. During these engineering assessments, the ITI-ALC team applied expert judgment to the processes and information relationships to identify potentials for improvement. The depot maintenance processes were analyzed using the following techniques:

1. Initially focusing on activities with the greatest resource consumption.
2. Identifying unnecessary administrative tasks, approvals, and paperwork for removal.
3. Identifying, for removal, identical activities performed at different parts of the process.
4. Evaluating every significant activity in the process to determine its contribution to meeting combat command requirements.
5. Reducing the complexity of the process, including organizational communication.
6. Identifying ways to compress cycle time to meet or exceed customer expectations and minimize storage costs.
7. Identifying ways to facilitate the performance of activities.
8. Identifying ways to more effectively use capital equipment and the working environment.
9. Identifying single ways to perform an activity so all employees always do the activity the same way.

10. Identifying areas where the quality of inputs can be leveraged to improve the quality of the outputs.
11. Applying tools, equipment, and computers to routine activities to free up employees to accomplish more creative activities.

In addition, the team did the following:

1. Applied recommendations and/or lessons learned from reports of previous and ongoing process improvement activities in DoD and other federal government agencies (refer to Appendix B for summaries of these reports).
2. Collected and recorded process improvement recommendations from mechanics and other ALC personnel.
3. Applied best practices that were identified during visits to commercial organizations performing similar maintenance activities.
4. Performed benefit/cost analysis with business case analysts, functional experts and information engineers.

3.4.2.2 Simulations

The results of the data collection, modeling efforts and engineering assessments were tested using dynamic simulation. Various models provided the framework for the simulation (see Figure 3-5) along with the performance data collected from the ALCs. The modeling tool, ProSim, and a simulation product, WITNESS, were used to support the simulation objectives. Using these tools, timing constraints and resources for depot maintenance operations were defined. Characteristics of the individual processes were defined with of probability distributions appropriate to the depot maintenance environment. The conditional behavior of the system was studied to assess the flow rates, bottlenecks, idle time, throughput, cycle times, workload, and other dynamic properties. Recognizing the potential incompleteness of collected data, simulation supported what-if analyses to define performance boundaries. Potential business process improvements were simulated first, then slices of major process improvements were grouped into proposals. The result was a series of process improvement recommendations. Using these recommendations, the ITI-ALC team developed proposals to structure viable approaches for achieving the objectives.

Throughout the iterative process, groupings of process improvements were tested using SRA's TurboBPR2 and functional economic analysis modeling tools.

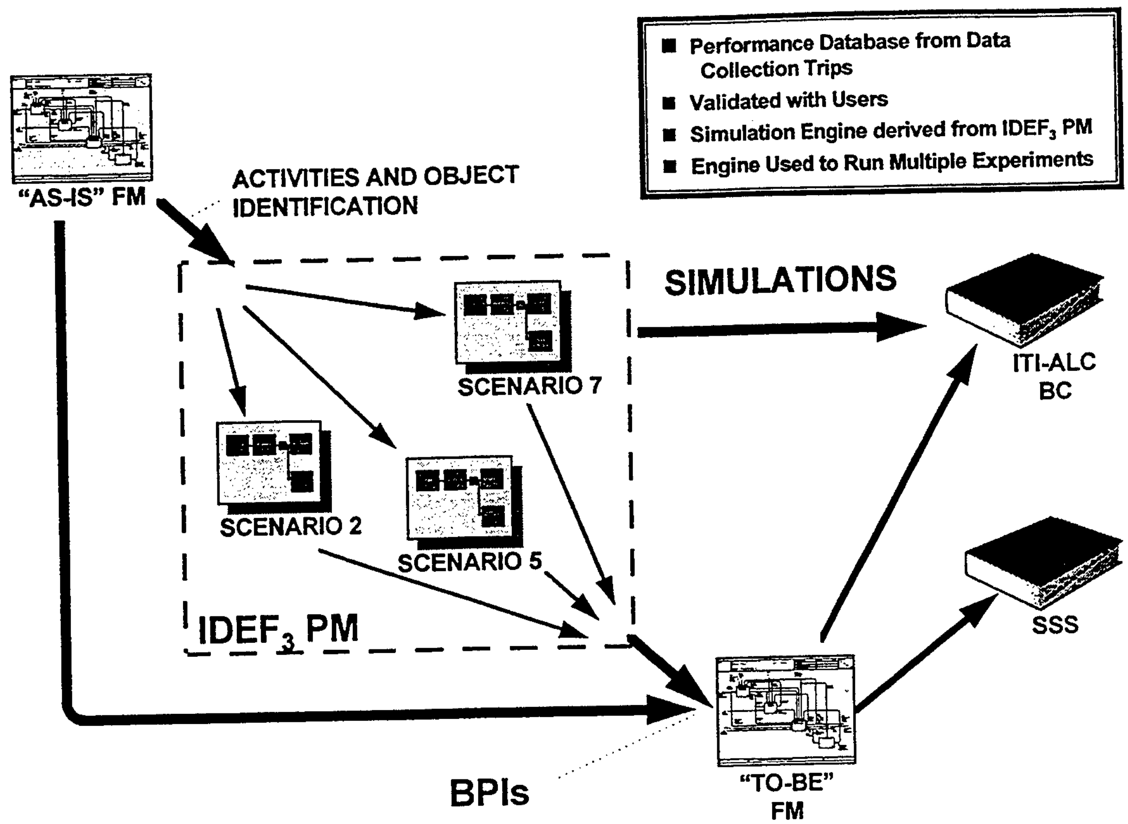


Figure 3-5. Process Model (IDEF$_3$) Support of ITI-ALC

3.4.3 BC Traceability

Information extracted from the engineering assessments, process model efforts, and simulations was used to help refine the ITI-ALC "TO-BE" Functional Model. In turn, the ITI-ALC "TO BE" Functional Model supported the ITI-ALC system requirements documented in the *ITI-ALC System/Segment Specification* (SRA, October 1995) and the business reengineering concepts described in the Business Case. Each of these steps to the process had a formal traceability effort as illustrated in Figure 3-3.

3.4.4 BC Possible Recommendations and Lessons Learned

During the development of the business case, the following were possible recommendations or lessons learned that were identified.

- **Domain objective were not available.**

  There were no AFMC-wide objectives dealing explicitly with the ITI-ALC domain. As a result, the ITI-ALC team inferred two specific priority objectives from the many general objectives included in AFMC and ALC planning documents. Those specific objectives were reduced operating expense and aircraft flow days for organic aircraft PDM, as discussed in the business case.

Also, there were no command-wide performance measures and targets (metrics) dealing with the domain that ITI-ALC was intended to affect. Accordingly the team inferred measures and targets from correspondence and data available within the depot maintenance domain.

- **Process improvement proposal structure required more than one improvement alterative.**

  This project team recognized that previous Information Technology (IT) investment projects typically presented decision makers with one alternative for improvement investment decisions. Therefore early on the ITI-ALC project incorporated an initiative to present a series of more than one option for the decision-maker. Each option more aggressive than the previous option in the series.

- **Two-way-blind test could not be fully implemented.**

  This project team recognized early in the program that there were not enough "equal" resources to conduct a true two-way blind test. One solution to this issue is to estimate enough resources in the project cost estimate. This is very expensive and may not be possible if equal team members cannot be found. If equal team members cannot be found a control team would also have to be formed to allow for the evaluation of variables between the two teams. In this age of "do more with less", this is not an acceptable approach. Using two core teams with one or two team members in both teams worked as long as everyone excepts the condition that the learning effect may bias the results. To minimize this bias, different team leaders were used and the SME was kept as "blind as possible" to the overall process so as not to subconsciously direct the two processes so they artificially converge. This plus an independent validation on the simulation half of the experiment (see the validation section above), allowed for results with small confidence intervals.

- **Another measure for economic analysis.**

  DoD and Air Force directives on economic analysis and the development of business cases contain two views of economic analysis.

  In the ITI-ALC project, the traditional view, defines the problem with the question, "what is the *maintenance cost* to accomplish organic aircraft PDM and how can we do it for less?" The answer obviously includes the cost of mechanics, engineers, and managers, the parts and raw materials incorporated into the aircraft product, the hangers and other facilities and the cost of supporting resources. It might be termed the in-house cost. It is not the major cost. This view deals with the problem from a systems perspective. It does not call into question the "out-of-service" costs associated with the relationship between the customer and the provider, AFMC. This problem is not new. It was raised by the DUSD(L) in 1995.

In a May 30, 1995 memo, the DUSD(L) made a statement in response to GAO/AIMD-95-110 Depot Maintenance Standard Systems. The statement included, "While the Department appreciates the GAO acknowledgment of process improvements achieved to date in depot maintenance, the GAO fails to realize the magnitude of achieving significant reductions in cost and flow days equating to a 30% reduction in the cost of ship overhaul, or processing two additional B-1 bombers through an ALC because of reductions in flow days. To illustrate, due to the complete reengineering of work processes and use of BAIM, the Navy has reduced overhaul time for the 688 class submarine from 24 to 20 months and now estimates all future 688 workloads will take 18 months. To put that change in perspective, the previous average for similar work was $81 million per submarine. However, in addition to reducing the cost of overhaul, weapon systems are expedited to the warfighter, increasing mission readiness. In addition fewer systems in the repair cycle equates to fewer systems needing overall, thereby achieving even more dramatic savings."

Without a value on the amount of time a system is out-of-service, the repair cycle days, it is difficult for managers to make investments to reduce them. The ITI-ALC system therefore developed a second view that combines total process and cost views into a total systems view. It includes the traditional view and takes into account the needs of and costs to the customer. In this view, the question is not only "what is the *maintenance cost*?"; but in addition, "what *are the costs to the customer*?".

What does the customer give up to obtain a PDM or incorporation of a modification package in an aircraft? A customer gives up two things. First, a customer pays the *maintenance cost* for each aircraft. That cost is relatively straightforward as reflected in the traditional view discussed above. Second, a customer relinquishes use of that portion of the aircraft's life spends in the maintenance process. For PDM the period will vary, but ranges from 100 to several hundreds of days per PDM cycle.

The cost to the customer of those days is less straightforward than the representing the *maintenance cost*. However, it was developed by the ITI-ALC team, based on similar industry practice.

To develop the cost to the customer, the ITI-ALC team obtained the Unit Flyaway Cost (UFC) for major aircraft in the USAF fleet from Air Force Instruction 65-503. This information for ten aircraft types is included in the table below. These items are included in the determination of a unit flyaway cost under Appropriation 3010 (Aircraft Procurement); airframe, propulsion, electronics, avionics, engineering change orders, if any, government furnished equipment, first destination transportation unless a separate line item, system and project management and system test and evaluation if funded by the aircraft procurement appropriation, warranties, recurring costs (both contract and in-house), nonrecurring cost (both contract and in-house), and advances buy cost (see Table 3-2).

Table 3-2. Aircraft Cost Information

Aircraft MDS	Inventory[1]	AFI 65-503 UFC (millions $)	UFC * 1.2 (millions $)	Value of One Aircraft Day ($)[2]
B-1	86	240.7	288.8	39566
F-15	584	24.2	29	3982
F-16	1588	14.5	17.4	2384
F-22	442	68.1	81.7	11197
E-3	29	114.3	137.2	18795
C-5	76	135.6	162.7	22300
C-130	877	14.5	17.4	2387
KC-135R	400	52.7	63.2	8664
C-141	223	41.2	49.5	6785
C-17	120	293.2	351.8	48199

[1] USAF Fact Sheets
[2] FY95 to FY94 conversion aircraft procurement weighted factor of 1.032.

Unit flyaway cost does not include: research, test, and evaluation appropriation expenditures, weapons and armament (except if part of the airframe, e.g., the 30MM GAU-81A gun on the A-10), peculiar ground support equipment, peculiar training equipment, technical data, initial spares and replacement spares.

In regards to flyaway cost and modifications, it is important to note that UFC reflects only those modifications which produced a new MDS. For example, the EF-111A was modified from the F-111A. Major aircraft modifications which do not produce a new MDS are not included. Thus, the unit flyaway cost for the B-052H reflects the unit flyaway cost as originally produced and then inflated to the constant dollars of a specific fiscal year. Since subsequent modifications to the B-052H did not produce a new MDS, the modifications are not included in the unit flyaway cost of the B-052H.

To account for research, development, test and evaluation, technical data, support equipment, etc., the ITI-ALC team increased UFC by 20%. The ITI-ALC team assumed 20 years in an aircraft life cycle.

To calculate the value of one aircraft flow day the team applied this formula:

$$\textit{Cost to the Customer for an Aircraft Flow Day} = \frac{(UFC)(1.2)}{(\textit{Life Cycle in Years})(365\ \textit{Days})}$$

Using this approach, the value of MSIP F-15 flow days of 174 days, is $692,868 per aircraft. The value of the 154 F-15 flow days provided to a customer, if flow days could be reduced to 20 days, is $613,226 per aircraft. The ITI-ALC team estimated Primary Aircraft Authorization (PAA) fleet sizes from USAF fact sheets or public literature. For a fleet of 584 F-15 aircraft, the value of the returned flow days is $358,125,152 over one 5 or 6 year PDM cycle.

3.5 SYSTEM/SEGMENT SPECIFICATION (SSS) CDRL SEQUENCE A008

The SSS documents the requirements for the ITI-ALC system. This system will encompass activities, processes, and information used to support mechanics, planners, controllers, and managers involved with PDM on aircraft and aircraft components.

3.5.1 SSS Development

The ITI-ALC SSS was created through an iterative development process beginning with an examination of the Data Item Description (DID) for a System/Segment Specification to determine the content for the SSS. This information was roughly allocated to the specific deliveries to establish customer expectations for the document as well as development priorities. An outline of the SSS was created with brief descriptions of the expected content of each section and an approach for development of the section or a potential source of the data for the section. Figure 3-6 depicts the major components of the SSS. The bulk of the SSS is devoted to requirements which fall into three basic categories: user/functional requirements, external interface requirements, and operational requirements (including segment requirements).

The primary focus for the SSS was determined to be the user/functional requirements (specified in user terminology) which would then drive the subsequent sections of the document.

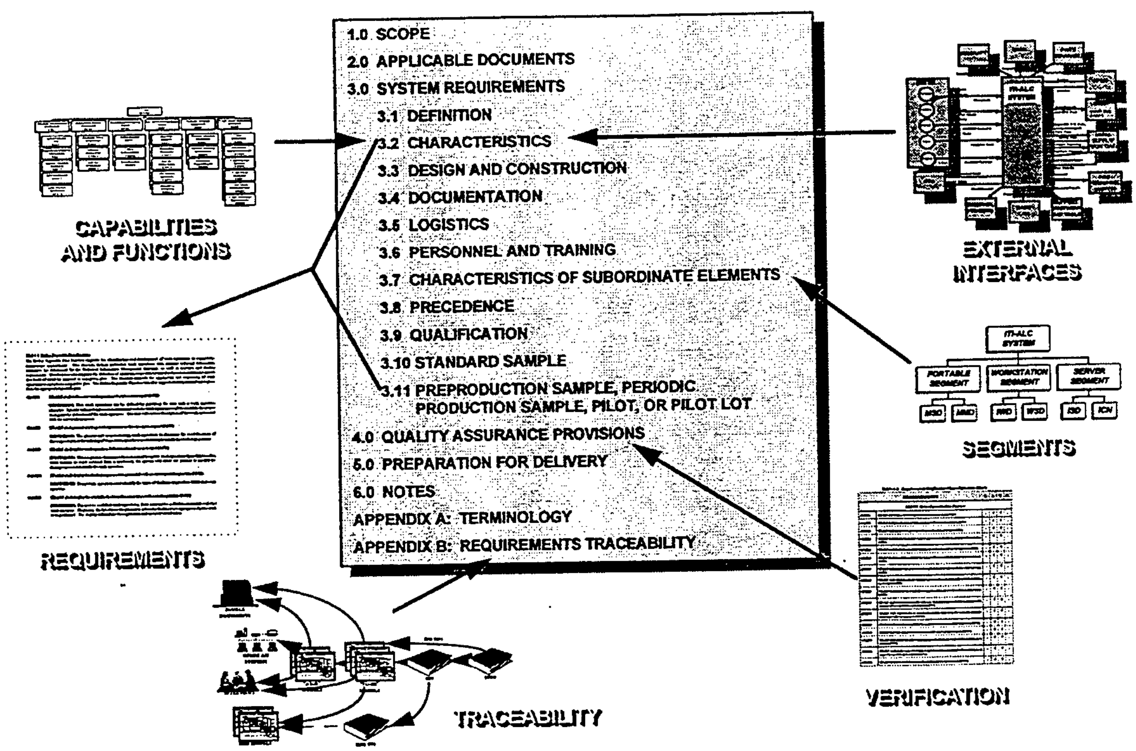


Figure 3-6. SSS Components

3.5.1.1 Development of Capabilities

The hierarchy to be used within the user requirements section was roughly defined through analysis of the ITI-ALC "TO-BE" Functional Model. First, the major capabilities were derived from the functional model, and nodes from the model allocated to the capabilities accordingly. A description of each capability was created to identify the intent of each capability and to provide the foundation for further development. This step was followed by an informal review of the capabilities and node allocation with the ITI-ALC project manager and the ITI-ALC system modeler to validate the structure and approach, as well as ensuring consistency with the system model.

3.5.1.2 Development of Functions

Once the capabilities were relatively stable, the functional model nodes allocated to each capability were analyzed in order to define the next level of breakout -- functions. Functions were defined within each capability and the nodes allocated to each function accordingly. Descriptions were written for each function to identify the intent of the function and to provide guidance for the next level of development for each function. The definition of functions was followed by an internal review with the previous audience (project manager and system modeler) and the addition of the functional modeler and the functional expert. This review focused on further validation of the capabilities, examination and refinement of the functions, and ensuring the complete coverage of appropriate depot maintenance activities in the planned structure for the SSS.

3.5.1.3 Development of Other Requirements

Following the definition of functions, further analysis of the "TO-BE" functional model was conducted to develop the requirements. The analysis was based on the nodes that were allocated to a given function, and the description of the purpose of the function (which implied certain requirements). The focus of this iteration was development of the user functional requirements in order to support the SSS Development Workshop (refer to Section 4.5.1.2). Other requirements such as the segment requirements, the external interface requirements, and the operational requirements were addressed after the user requirements were relatively stable and mature. All requirements were developed as succinct, concise, one-sentence statements reflecting what the system needed to do. The "TO-BE" functional model node number from which the requirement was derived was appended to the end of each requirement to support requirement tracing. Each user requirement was also accompanied by a small paragraph labeled **"DISCUSSION"** that provided additional detail for understanding the associated requirement as well as possible implementation considerations. Figure 3-7 depicts the organization of the SSS functional requirements.

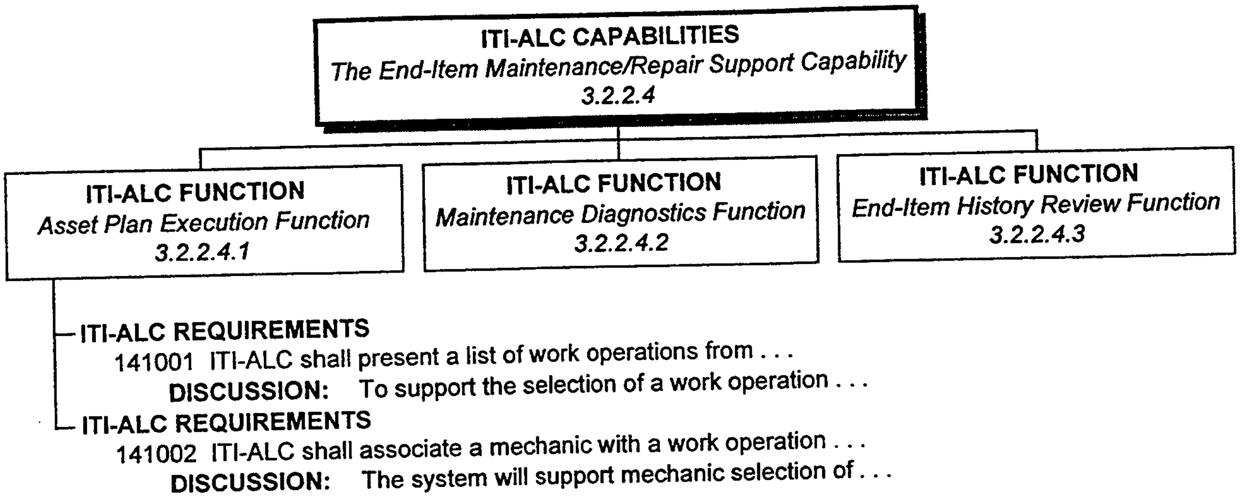


Figure 3-7. Functional Requirements Organization

3.5.1.4 External Interface Requirements Development

The external interface requirements were developed to be consistent with and supportive of the user requirements. The external interface requirements were derived from the relationships to external systems as reflected in the *ITI-ALC Architecture Report*, particularly the "TO-BE" Functional Model and the System Model. These requirements reflect the type of data to be passed between ITI-ALC and each identified system at a high level. Following delivery of the preliminary final SSS, an internal meeting was held to review, validate, and reconcile the information reflected for each external interface with the information contained in the System Model. The attendees for this meeting were the system modeler, the SSDD author, the project's functional expert, and the SSS author.

3.5.1.5 Operational Requirements Development

The operational requirements include the requirements for system quality, security, reliability and maintainability, and documentation. These requirements were incorporated into the preliminary final of the SSS and were basically copied from the IMIS requirements for these same areas. Changes were made as appropriate to reflect things peculiar to the ITI-ALC system.

The requirements for the segments were also developed as part of the operational requirements for the system. Initially, six segments were defined and reviewed internally by the ITI-ALC team. Descriptions were written for each segment to address the purpose of the segment, the primary user of the segment, and general characteristics for the segment. It was determined that some of the operational requirements to be defined according to DID were more applicable at the segment level. Consequently the requirements for computer resource reserve capacity, physical characteristics, and environmental requirements were all defined at the segment level. Requirements were written for each segment addressing each of these areas. These requirements were included in the draft version of the SSS. Comments from the customer indicated the proposed segments and associated requirements were premature in the level of detail provided. The segments were redefined as three more generic segments from which the original six hardware items could be derived representing one implementation of the segments. Figure 3-8 depicts the revised segments. These three segments along with a more generic set of associated requirements were incorporated into the final SSS.

The representation of segments within the SSS was revised to reflect more generic classes of items with associated generic requirements instead of specific devices. The original six hardware items were included with the definition of the three segments as indicated in Figure 3-8 to provide context for each segment as a representation of a possible implementation of the segments.

The six hardware items were further defined in the draft version of the SSDD. Care was taken when identifying the three segments to ensure that the six hardware items in the SSDD could be derived from the segments as a possible implementation. The basic philosophy for the segments is that multiple devices may be used to implement a given segment, but it is not imperative that a single device satisfy all the requirements for the segment. However, if multiple devices are used to represent a segment, those devices must collectively satisfy all the requirements for that segment.

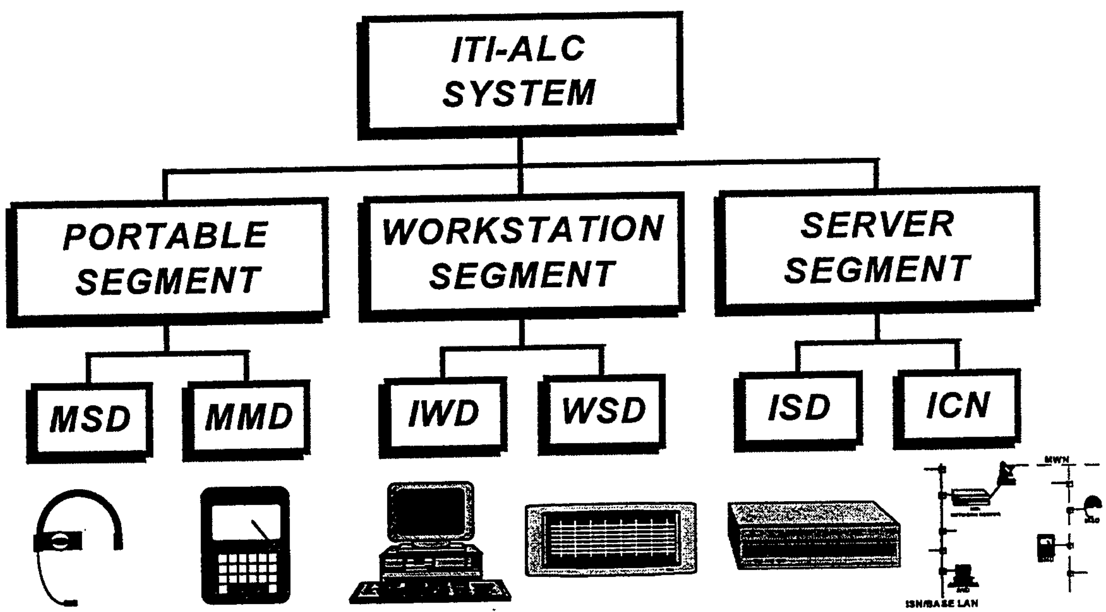


Figure 3-8. ITI-ALC Segment Implementation Concept

3.5.2 SSS Validation

Throughout development of the SSS, multiple internal reviews were conducted, each with more participants than the previous review as appropriate to ensure the integrity of the review, to keep the reviews manageable, and to focus on the project members most affected by the information represented in the document. Figure 3-9 is a graphical representation of the process used to develop the ITI-ALC SSS.

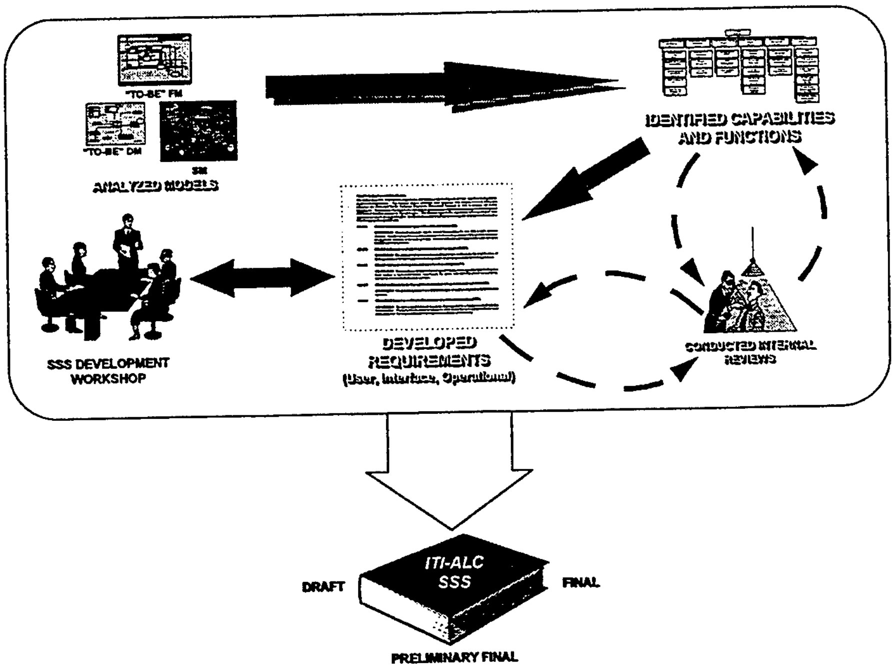


Figure 3-9. SSS Iterative Development Strategy

Once the requirements were defined, a "strawman" version of the document was compiled for use in the SSS Development Workshop. The purpose of the workshop was to review, revise, and validate the proposed ITI-ALC system (business processes, system requirements, system hardware) as represented in the SSS. The output of the workshop was a revised SSS that formed the basis for the second delivery (preliminary final).

The workshop had participants from four ALCs: OO-ALC, SM-ALC, WR-ALC, and OC-ALC. The intent was to have representation from all five ALCs, but due to a miscommunication the SA-ALC was not represented. The backgrounds of the ALC participants consisted of planners, managers, mechanics, an industrial engineer, and F-22 personnel. Additional participation consisted of our functional expert, functional and system modelers, representatives from AL/HRGO, and SRA project management. The selection of participants was designed to obtain a cross-functional set of people representing the aspects of depot maintenance that have been our primary focus.

The workshop was held for 3 days beginning with an overview of the proposed ITI-ALC system and a review of the capabilities contained in the SSS with a brief discussion of the functions associated with each capability. Participants were divided into three teams responsible for completing the group exercises and presenting the work accomplished by each team. The results of these group exercises were revisions to the descriptions of the capabilities and functions, revisions to the requirements, and miscellaneous changes including deletion of several requirements and one function.

Following the workshop, the changes were incorporated into the preliminary final version of the SSS. A report identifying the changes to the SSS resulting from the workshop was developed and provided to the ALC participants.

3.5.3 SSS Traceability

Like quality assurance, traceability should be accomplished throughout the process of development as well as a final verification step near the end of the development process. The ITI-ALC team used an innovative approach by developing the "structure" of our process so that traceability was done **automatically** and not as a "second step." As can be read in the sections above, each requirement was developed almost directly from the description of a given node within the "TO-BE" Functional Model. This allowed for automatic trace to that node as well as the indirect trace back to at least one user interview and to the entities in the TO-BE Data Model. To ensure this traceability, a formal trace step was also performed.

Formal traceability between the ITI-ALC Architecture Report and the ITI-ALC SSS consisted of tracing the system functions and functional interfaces within the SSS to the activity nodes of the "TO-BE" models in the architecture report from which they were derived (see Figure 3-3). Within the SSS, each system function contained a set of individual system requirements which were separately identified and managed to facilitate traceability. As a result, each requirement within a given system function of the SSS also traced to the "TO-BE" model activity node from which the function was derived. Additionally, traceability from the ITI-ALC SSS to the IMIS SSS was established was ensure that the ITI-ALC architecture complimented the IMIS architecture.

3.5.4 SSS Possible Recommendations and Lessons Learned

The process used to develop the ITI-ALC SSS was rigorous, systematic, and successful. There were several lessons learned from implementing this process. Also, some possible recommendations may apply.

- **SSS development workshop should be longer.**

  The workshop was three days long which only allowed time for revising the user requirements. The workshop should be five days long to allow time to examine and revise all requirements in the SSS with focus on the user requirements, external interface requirements, and segment descriptions and requirements.

- **SSS workshop instead of one of the three deliverables.**

  If a workshop is used as a means to develop the SSS, there should only be two deliveries of the document. There should be one delivery (preliminary final) reflecting the results of the workshop and a second delivery (final) approximately three months later to address any outstanding details or issues resulting from customer review of the post-workshop version. The premise of two deliveries stems from the idea that the workshop is supported by the appropriate personnel that can and should influence the requirements within the SSS, negating the need for three deliveries to achieve the desired content level.

- **Iterative requirements development is required.**

  The primary categories of developmental requirements within the SSS are functional requirements (representing user requirements), external interface requirements, and segment requirements. The functional requirements should be defined first and should determine the need and provide the basis for the external interface requirements and the segment requirements. As requirements are developed, each category (functional, external interface, and segment) should be revisited and revised accordingly (iterative process) until "all" requirements have been defined for the system.

- **The concept for how to specify and organize an effective SSS was not consistent among all individuals involved in its development, even though a DID was identified within the contract.**

  The SSS was one of the key documents developed during the ITI-ALC program in that it specified the detailed requirements for the "TO-BE" ITI-ALC process as well as the technologies used to implement the process. The true success of the ITI-ALC program will not be determined until the SSS is used as the guide for designing, developing, and implementing the ITI-ALC system. Given the importance of the SSS, the "correct" DID, and a full understanding of that DID, should have been established early-on by all representatives of the customer and should have been reinforced throughout the program. The reinforcement would ensure that new program personnel understand the history and goals of the work performed and would eliminate the possibility of unnecessary program direction changes. These variations in SSS expectations and concepts within the customer team required significant time and effort to discuss and a large amount of rework.

3.6 SYSTEMS DESIGN AND ANALYSIS

3.6.1 System/Segment Design Document (SSDD) CDRL Sequence A014

The ITI-ALC SSDD was created through an iterative development process beginning with an examination of the DID for the SSDD to determine the content of the SSDD. This information was roughly allocated to the specific deliveries to establish customer expectations for the document as well as development priorities. An outline of the SSDD was created with brief descriptions of the expected content of each section and an approach for development of the section or a potential source of the data for the section. Figure 3-10 depicts the major components of the SSDD and where information that supported each component can be found.

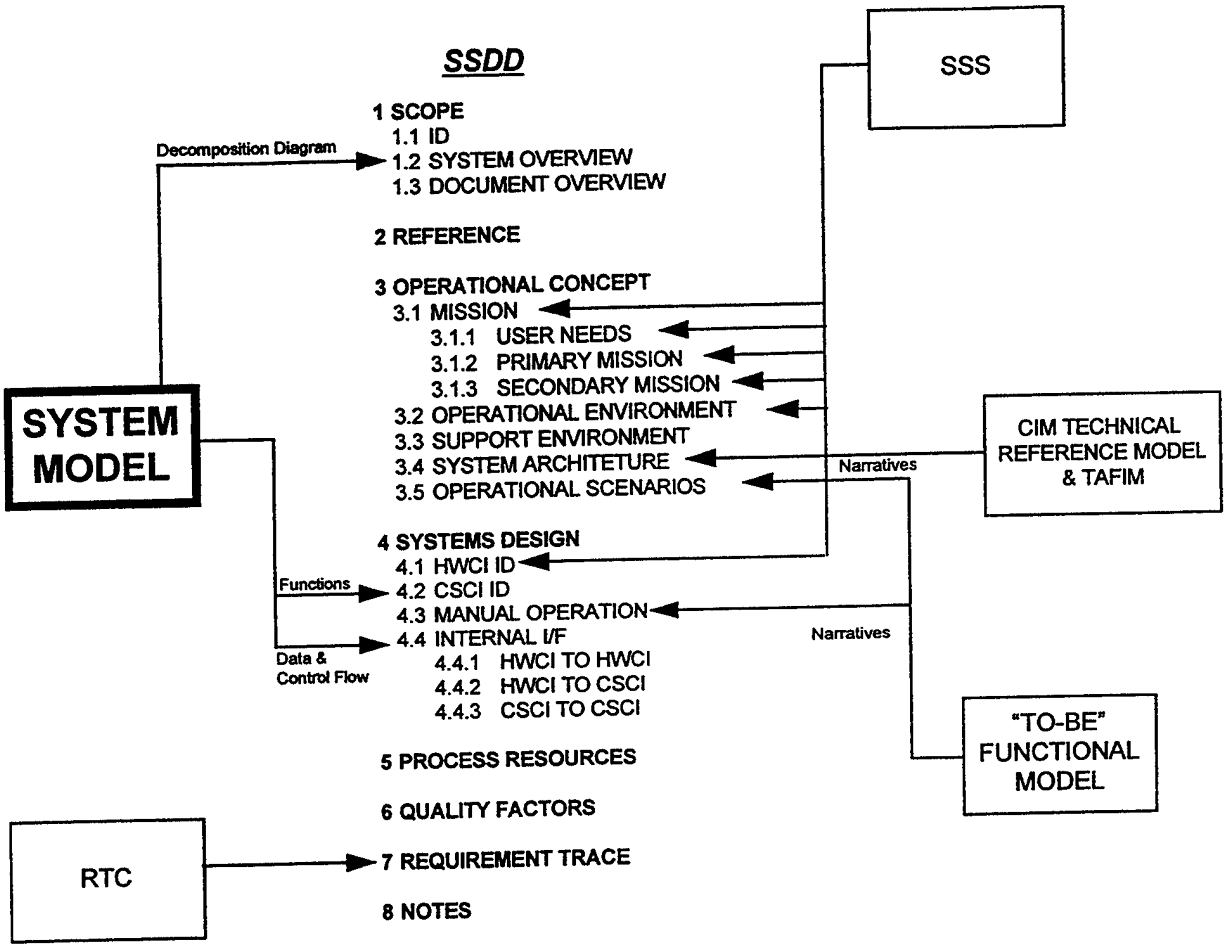


Figure 3-10. Information Flow to SSDD

3.6.1.1 SSDD Development

The system development process for phase one of the ITI-ALC project involved developing functional, data, and process models. Also developed were the system model, SSS, and culminating with the SSDD. Throughout the development of each release of the SSDD multiple internal and customer reviews were conducted to help ensure the integrity of the document. Internal reviews were conducted by functional experts and project model and document authors.

The ITI-ALC project's approach was to work on the specific sections of the SSDD after completion of associated supporting sections of the SSS and system model documents were through at least their first iteration and reviewed by the customer. As later iterations of the documents were reviewed new information was incorporate into the next version of the SSDD. This allows for a shorter project schedule because of the overlapping of the development schedule of each document.

Once the appropriate sections of the SM had been completed and reviewed, the resulting model was used to identify portions of the system overview as well as the software portion of the system hierarchy. The SM also helped CSCI-to-CSCI interfaces, internal CSCI interfaces, external interfaces, and inputs and outputs of each process. Figure 3-10 represents how the SM was used to directly develop major components of the SSDD.

Also shown are other important sources of information for the SSDD, such as the SSS. The SSS was instrumental in the development of the system's mission and especially the user's needs. The SSS defined, in a concise fashion, the specific needs a system would have to fulfill in order to satisfy the system's mission, along with each type of users needs. The functions defined in the SSS along with the users interfaces section, and the SM enabled us to define the system's software components used to fulfill functional and user requirements. The External interface requirements section of the SSS was also used to help determine what functions and hardware would be needed to communicate to other systems. The Operational requirements defined in the SSS were a major source used in the development of the hardware segments. These requirements spelled out the purpose of each segment, user of the segment and described the general characteristics of the segment. This information helped define the look, feel and capabilities of the final segments.

The last major part of system development was the architecture of the ITI-ALC system. The *Corporate Information Management (CIM) Technical Reference Model* and DoD's *Technical Architecture Framework for Information Management (TAFIM)* documentation were excellent starting points to an overall system architecture for ITI-ALC. The *CIM Technical Reference Model*, populated with approved standards, was used as a major source of information. It was determined that following a standard would ensure the resulting system would be developed using solid approved and proven services thus avoiding the potential pitfalls of yet unproved services. Furthermore, the resulting system would be more open to existing and future system built under the same premise.

To ensure that the ITI-ALC system truly meet the users needed, a few additions were added to the standard services. These include: C, C++, IETM-M, D and Q and Communications service. The C and C++ programming languages were added to help better create the user interfaces and system communications. With these languages, a large amount of versatility and reuse potential can be used to enhancing the overall final product. The IETM specs were added because The ITI-ALC system can be characterized as an IETM based system and the CIM model didn't contain any IETM type specifications. The communication services section was added because the ITI-ALC system will have to communicate with other systems including legacy systems that were not developed using open system concepts and therefore will not conform to standards identified in the network services of *CIM Technical Reference Model* or TAFIM.

3.6.1.2 SSDD Validation

The systematic and rigorous process used to develop the SSDD is shown in Figure 3-11. The development process is based on information and analysis of other models and documents that have undergone many reviews conducted by functional experts, modelers, authors, designers, and developers during the performance of the ITI-ALC program. Both the SSS requirements and SM

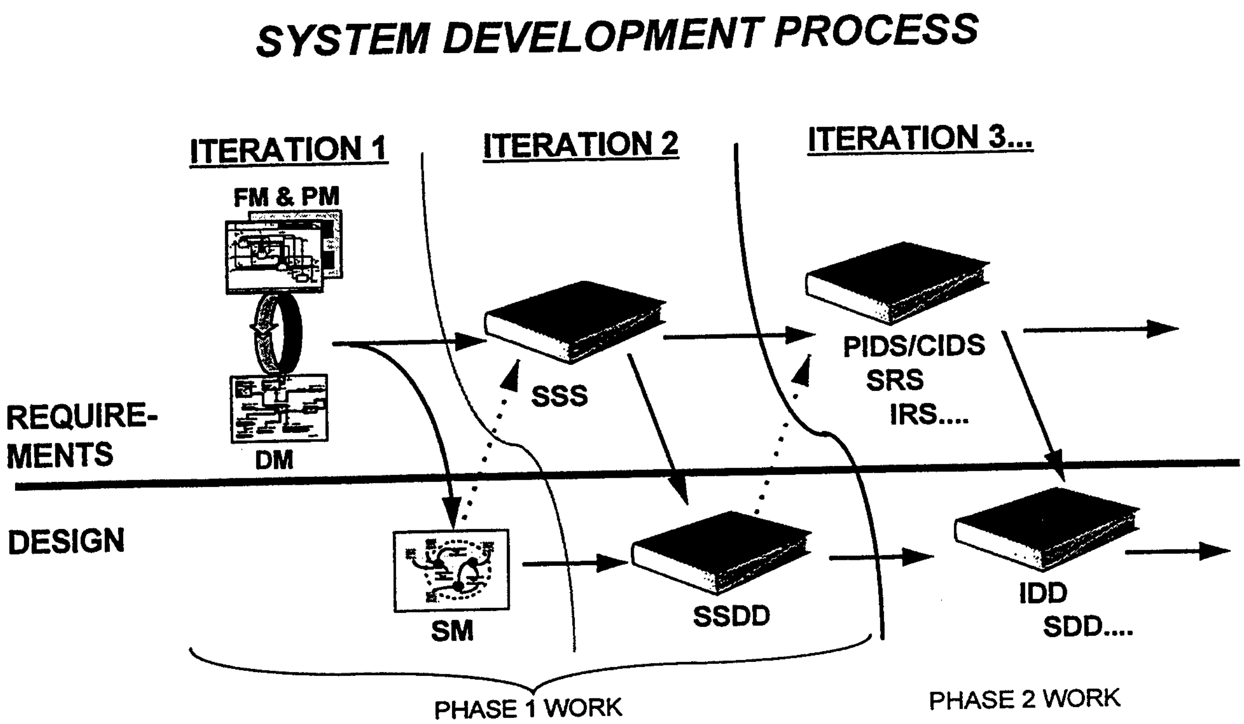


Figure 3-11. Iterative Development of a System

design were derived from requirements established in the functional, process, and data models. To ensure consistency between the two methods, reviews were completed. Both documents were essential in the development of the SSDD.

This structure along with review of the document help to ensure that a valid design was generated. The focus of the SSDD review process addressed two perspectives. First, the reviews ensured that: (1) correlation exists between the SSDD and the "TO-BE" versions of the FM and DM, (2) the SSDD conforms to the DID, (3) all terms are fully defined in the glossary, and (4) the correlation with other depot maintenance information is maximized. Second, the reviews ensured that the document provided an understandable representation such that an effective validation process can be performed. Both perspectives involved using walkthroughs and peer reviews by internal functional experts and systems/software engineers.

One peer walkthrough review was conducted on this document as a desk top review. Peer reviews provide early visibility into the status and quality of the product with ample time to take corrective action if progress and quality are not at acceptable levels. One subject matter expert walkthrough review was conducted to ensure that the SSDD was usable, as well as comprehensive and compliant with project needs. Upon completion of these reviews, the review leader collected the reviewer's comments, evaluated the results, and defined any action items.

Next, this model was validated. The focus of the validation process was to ensure that the SSDD provided a complete and accurate representation of the ITI-ALC system. Because the "TO-BE"

FM controlled the baseline processes that must be supported by the system specified by the SSDD, the validation of the FM provided a significant step toward the validation of the SSDD. The validation of the linkage between these entities was facilitated by the tracing capability provided by the RTC.

3.6.1.3 SSDD Traceability

Since the SSS encompassed all requirements applicable to the ITI-ALC system and served as a basis for the SSDD, the SSDD need only trace directly back to the SSS. Traceability between the ITI-ALC SSS and the ITI-ALC SSDD consisted of tracing the system functions, requirements, and functional interfaces of the SSS to the Hardware Configuration Items (HWCIs), CSCIs, and manual operations contained in the SSDD. For SSS-to-SSDD traceability, each requirement within the SSS traced to the component(s) within the SSDD that satisfied that requirement and to which that requirement was allocated. Some SSS requirements were allocated to either a HWCI or CSCI, some were allocated across multiple HWCIs and/or CSCIs, and others were allocated to manual operations. SSS requirements were written to facilitate allocation to single configuration items and to minimize the need for allocation across multiple configuration items.

3.6.1.4 SSDD Possible Recommendations and Lessons Learned

The following are possible recommendations and/or lessons learned were discovered during the development the SSDD.

- **Overlap/parallel development of project deliverables.**

  While overlapping the development of project documents such as the SSDD and the SSS helps reduce the project's schedule, this overlap also can cause extra, non-value-added work when changes are made, due to the ripple effect. The solution used on this project didn't eliminate this rework completely, but did reduce it to tolerable levels. The primary way this was done was to structure the development approach to take advantage of the iterative nature of the system development process (see Figure 3-11). The "TO-BE" models represented requirements for the system and were baselined early enough in the process to be used to develop the SM. The SM then became the major input into the SSDD. Because both the SSS and the SSDD were ultimately derived from the same sources, the SSDD fulfilled all the requirements identified in the SSS even with them being developed almost simultaneously. This fact was validated using the traceability process outlined above. This innovative approach to parallel development allowed shorter schedule time as well as flexibility to change.

3.6.2 ITI-ALC-to-IMIS IPS Demo Analysis - CDRL Sequence A011

The results of the effort outlined below have all been documented in the Depot Requirements Compared to IMIS Prototype Capabilities Final Report (CDRL number A011).

3.6.2.1 IMIS Demo Analysis Development

The process shown in Figure 3-12 illustrates the process used to develop the comparison document.

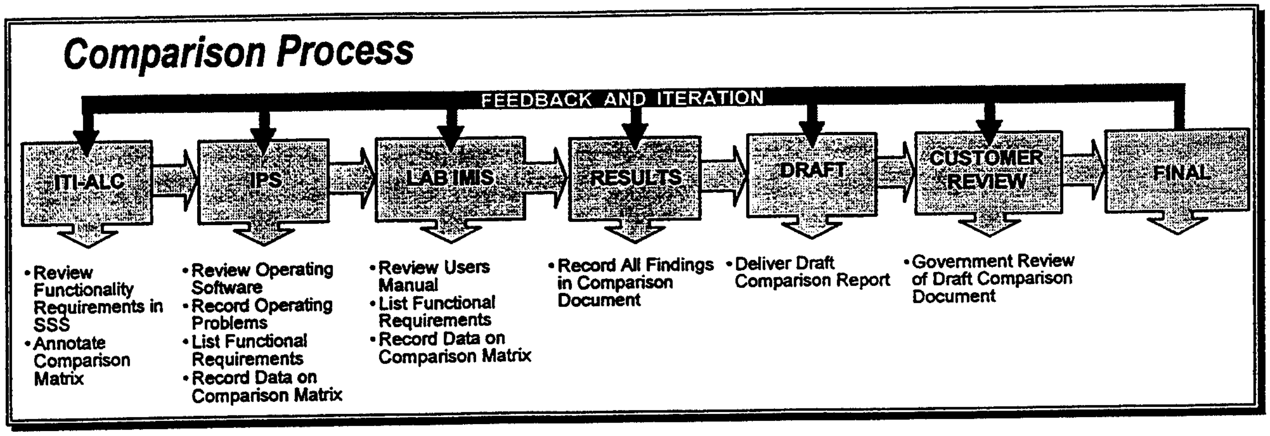


Figure 3-12. Comparison Process

The ITI-ALC-to-IMIS IPS demo analysis was accomplished by comparing the functional requirements for ITI-ALC as defined in the SSS, the functionality of the Lab IMIS as defined in the Lab IMIS user's manual, and the functionality of the DOS/Windows version of the IPS. The functional requirements of the ITI-ALC system were mapped to the functions of the Lab IMIS and the IPS. The mapping process consisted of a desktop review of the documentation for the ITI-ALC and Lab IMIS systems and operating the IPS on a 486 desktop PC with 16 MB of RAM using DOS 6.2 and Windows 3.1. No documentation was provided for the IPS; therefore, the mapping was based on titles of the functions and data fields presented within each of the fields.

3.6.2.2 IMIS Demo Analysis Validation

The results of the comparison are included in the comparison document as a matrix which is explained in Figure 3-13. The matrix lists the functions of the IPS and Lab IMIS in the first two rows. The ITI-ALC functions are listed in the column along the left side of the matrix. The highlighted cells in the "Lab IMIS" row are IPS functions that are not available in the Lab IMIS and the highlighted cells in the "IPS function" row are Lab IMIS functions not supported by IPS.

Columns that have horizontal hatches identify the IPS and Lab IMIS functions that are not required by ITI-ALC. The ITI-ALC functions that have the entire row highlighted are not available in either the IPS or Lab IMIS. The rows that are not highlighted are the functions of ITI-ALC that are a part of the IPS and Lab IMIS. The ITI-ALC functions are further identified by coding to the IPS and to the Lab IMIS. The code on top of the cross mark (A or B) defines how the ITI-ALC function relates to the corresponding IPS function. The code below the cross mark (1 or 2) defines how the ITI-ALC function relates to the Lab IMIS function.The definition of the comparison codes are:

<u>Category A</u> – This category includes those IPS functions that support ITI-ALC. Category A includes those IPS functions that are the same as ITI-ALC with different names. (e.g., work order in the IPS is the same as asset or reparable plan for ITI-ALC).

<u>Category B</u> – This category includes those IPS functions that could support ITI-ALC but are not implemented.

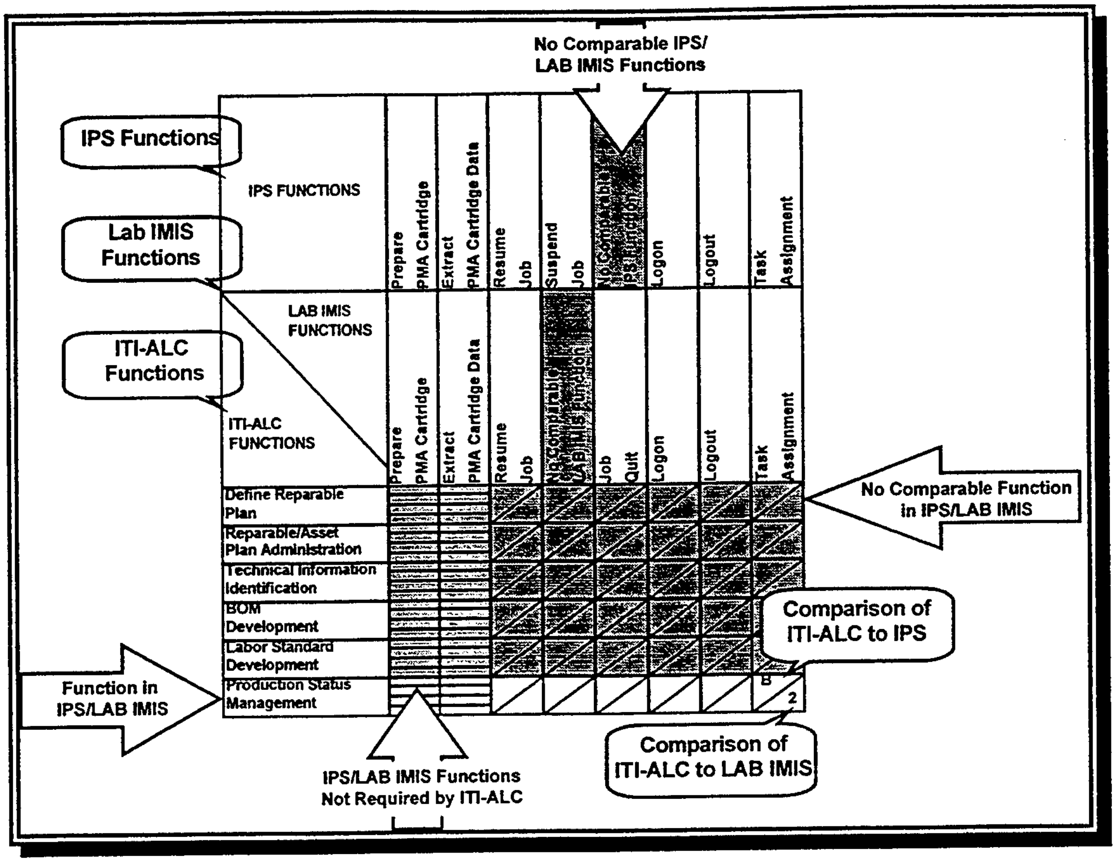


Figure 3-13. Comparison Matrix Structure

Category 1 – This category includes those Lab IMIS functions that map to identical functions of the ITI-ALC system. The category 1 functions are those that are required for utilizing the IMIS technology at both the O- and D-levels of maintenance. The functionality includes both the PDM and backshop maintenance activities conducted at the ALCs.

Category 2 – This category includes those Lab IMIS functions that are mappable to comparable functions of ITI-ALC; however, the Lab IMIS requires additional refinements such as additional or reduced data fields, interfacing with different legacy systems, a capability to determine which information is correct, and different data transfer rules.

In all but three instances where the ITI-ALC system functions map to IPS and Lab IMIS, there are multiple mappings between a single ITI-ALC function and the IPS and Lab IMIS functions. The reason for the multiple mappings is that the ITI-ALC system is in the definition stage while the IPS and Lab IMIS are defined and developed systems. Therefore, the ITI-ALC system functions are at a higher level than the developed systems and the functions of IPS and Lab IMIS were mapped to functions that were encompassed in the higher level ITI-ALC system functions.

3.6.2.3 IMIS Demo Analysis Traceability

Detail mapping of the ITI-ALC system functions to the functions of the IPS and Lab IMIS was performed as part of this effort. The mapping of the functions was performed by using the function descriptions in the ITI-ALC SSS and comparing them to the functionality that is described in the Lab IMIS user's manual and the functionality performed by the IPS software.

3.6.2.4 IMIS Demo Analysis Possible Recommendations and Lessons Learned

During the performance of the IMIS Demo Analysis, the following possible recommendations and/or lessons were identified.

- **System documentation is needed.**

  Comparing a developed system with a system undergoing requirements definition presented a unique challenge that would have been reduced if the documentation for the developed system had been provided.

- **Working with the software of the developed system was very useful for determining the functionality of the system.**

  Reading the documentation for a system helps understand the intended functionality of the system and provides the mechanics necessary to maneuver within the system. Having gained this fundamental understanding, getting hands-on experience is the only way of understanding the real system capabilities necessary to perform an indepth evaluation and comparison.

- **Development system source code would have enhanced the comparison.**

  The comparison document could have provided another level of usefulness if the software code had been provided. The code would have allowed the identification of the changes required in the code rather than the functions that require change.

3.7 FINAL DEMONSTRATION/EVALUTION PLAN - CDRL SEQUENCE A010

The ITI-ALC demonstration effort will be conducted on a PDM line at a selected ALC site. The objective of the ITI-ALC demonstration is to compare the effectiveness and efficiency of mechanics and other depot PDM personnel when using new processes and technologies described in the *ITI-ALC System/Segment Specification* and the *ITI-ALC Business Case.* To do this, the planning for the demonstration was done like a formal test planning or experiment design effort. In general, all formal testing is done with one of four techniques: (1) demonstration, (2) test, (3) analysis, or (4) inspection.

The *ITI-ALC Final Demonstration/Evaluation Plan,* resulted from this effort utilized the first three of these techniques. The system/process will be authenticated employing the technique of either a demonstration or a test. Analysis will be used, among other things to prove hypotheses (e.g., using the simulations created during the first phase of this project) that cannot be effectively proven using any other technique. The intent of a demonstration will be to show some aspect of the processes or technologies that could be implemented in a production-level

ITI-ALC system. The intent of a test is to obtain empirical data so that formal analysis can be conducted on a new process or technology to assess performance. In all cases performance data from individuals using the new methods of performing a given tasks will be compared to the performance data of individuals who are using standard (current) methods.

3.7.1 Demonstration/Evaluation Plan Development

In any test or demonstration being conducted like an experiment, the "experimenter" is attempting to draw certain inferences or make a decision about some hypothesis that concerning the situation being studied. Experimental designed (which this effort could be classified as), are used to organize complicated experiments and to help reduce the error in data collecting. Randomization was employed in this design to help average out the effect of the many extraneous variables which are present in an experiment of such a complex and diverse activity as PDM. Other factors (such as which system a subject used or the experience of the subjects) were purposefully varied in the plan in order to make the results more valid for a large variety of situations which occur in the general population of all the ALCs. By using factorial designs, the certain factors could be studied in one experiment as well as the interrelationship between factors. This planning effort emphasized three important developmental phases of the ITI-ALC project in Phase II:

1. Experiment
2. Design
3. Analysis

For the experiment, much effort was put into a statement of objectives. This sounds like an obvious first step; however, in practice it often takes quite a while to get general agreement as to the objective of any long term effort. Much time was spent reviewing and analyzing all points of view to establish just what the Phase II experiment will be intended to accomplish. This carefully constructed statement goes a long way to define the Phase II effort for ITI-ALC: "to compare the effectiveness and efficiency of mechanics and other depot PDM personnel when using new processes and technologies described in the *ITI-ALC System/Segment Specification* and the *ITI-ALC Business Case.*

The *ITI-ALC Demonstration/Evaluation Plan, Final*, dated 19 December 1995, was dedicated to describe the "design" of the experiment for the ITI-ALC Phase II project. Many times an experiment is agreed upon, data is collected, and conclusions are drawn with little or no consideration given to "how" the data was collected. Questions such as "How many observations?" -- "When?" -- "How many standard deviations are needed for an "outlier?" -- "What is the size of the population and what size is needed for the sample?" -- "What is the order/sequence of experiments?" The influence of the learning effect were all taken into consideration when designing the experiments for Phase II of ITI-ALC.

The final step taken in this effort was analysis. This includes the approach to data collection, type of data to be collected, data reduction, and identification of the statistics to be used in making decisions about various aspects of the experiment. In this case, the Analysis of Variance (ANOVA) will be used for all statistical analysis. Descriptive and inferential analysis will also be done on the subjective data collected with forms and during interviews.

3.7.2 Demonstration/Evaluation Plan Validation

The only formal validation for the resulting documentation of this effort will be the successful completion of the demonstrations cited for Phase II ITI-ALC. The document and the ideas/concepts included in that document did however go through a set of informal and formal reviews as part of the standard SRA development and Quality Assurance (QA) process.

This process typically consists of two or three events with additional work due to comments from the customer's formal reviews expected. All review activities are documented using SRA's QA Activity Evaluation Form. The *ITI-ALC Final Demonstration/Evaluation Plan* QA reviews was subject to follow the following requirements.

3.7.2.1 Deliverable (Final) Review

This review checks that all action items from previous QA activities are resolved and that the item is ready for delivery. This review should take place (at a minimum) two days prior to delivery. The ITI-ALC project will include three layers of quality reviews.

1. ITI-ALC data administrator(s)
2. QA editor
3. Quality Assurance Official (QAO) – "spot checks"

The commanding position of the person (Director of Dayton Operations) performing this task will ensure autonomy for the quality review. In all cases specific quality criteria will be identified (using the QA Certification/Release Form) and all comments will be in written form. The criteria for acceptance for all of the deliverables on the ITI-ALC project will be taken from the section of the SRA QA Manual pertaining to acceptance criteria. The form will be kept "on-file" with the deliverable. Generic acceptance criteria can be found included in Attachment C of the ITI-ALC Quality Assurance Plan (QAP). Specific acceptance criteria will be developed per deliverable or product and are included in the formal documentation folder for the deliverable.

3.7.2.2 Review Based on Customer Comments

This review assesses the scope of the customer's comments and the amount of rework required. Significant rework will require that an additional draft review be held. Materials used for this review are the customer comments and the deliverable itself.

NOTE: The possible recommendations and/or lessons learned on this subject, it did not seem the customer had sufficient resources to perform a significant critique of this document or effort.

3.7.2.3 Peer Review

Peer reviews provide early visibility into the status and quality of the product with ample time to take corrective action if progress and quality are not at acceptable levels. This review checks the content of the deliverable to assure that it is both comprehensive and correct. The review is performed by experts in the subject matter as well as "users" of the document/product. This will ensure that the documents are usable as well as comprehensive and compliant with requirements. Material for this review includes the draft deliverable, product requirements/standards, deliverable scorecard that allows the review to identify strengths and weaknesses within particular section(s), content checklists which list the defined success criteria, and a review agenda. For CDRL A010, the peer reviews done were all done as desk top reviews.

3.7.2.4 Presentation

For many documents it is more important that the general ITI-ALC team understand the concepts included in the document as opposed to critiquing the document. The concepts of the experiment documented in CDRL A010 were presented to the group as a whole to solicit ideas and to ensure everyone understood the intent. This technique also helps future reviewers understand the overall concept before reading the document.

3.7.2.5 Audit

An audit is a structured examination/evaluation by the QAO of a defined process to determine whether or not the process is being implemented in accordance with established guidelines and whether or not the products of the process meet established acceptance criteria. The QAO will conduct periodic audits of the various processes (e.g., configuration management). Prior to an audit, or process review, the QAO will notify all parties of the impending audit, describe the audit process to be followed, provide a schedule for all audit activities, and provide a copy of the evaluation criteria. The QAO will conduct the audit and document all findings. QA will then report on the outcome of the audit. If no problems are identified or only minor corrections to the process are required, the QAO will meet with the parties to determine appropriate follow-up procedures (e.g., verify corrections via inspection or during next scheduled audit). If the results of the audit indicate that major corrections to the process are required, the QAO will issue a Quality Action Item (QAI) indicating the problem and providing a suspense date for resolving the problem. Upon completion the QAO will update the QA database with audit results and, if necessary, modify the schedules to show additional audit activity.

3.7.3 Demonstration/Evaluation Plan Traceability

The traceability requirement for the demonstration test effort is a trace back to the Business Process Improvements identified as part of the overall Phase I effort of ITI-ALC and documented in the *ITI-ALC Architecture Report* and the *Business Case for ITI-ALC*. Table 3-3 lists all the BPIs and whether they relate to the specific demonstrations and tests. The traceability will help ensure the specific benefits of a BPI can be measured during the demonstration and that the Business Case can be validated. For text descriptions of this BPIs, reference the given section of the *ITI-ALC Architecture Report* and/or the *ITI-ALC Business Case*.

Table 3-3. BPI to Demonstration/Test Correlation

#	BPI Recommendations	AR* Ref.	BC* Ref.	Planning Test	Debriefing Demo	WP* Test	TS* Demo
1	Process and Terminology Coordination	4.2.1	C.1.1	X	X	X	X
2	Planning Process Enhancement	4.2.2	C.1.2	X			
3	Acquire Parts	4.2.3	C.1.3	X		X	X
4	Data Sharing Among All Levels of Maintenance	4.2.4	C.1.4	X	X	X	X
5	Production Responsibility Centers	4.2.5	C.1.5		X	X	
6	Component Parts Acquisition Policy Changes	4.2.6	C.1.6	X		X	X
7	Visibility into Part Availability	4.2.7	C.1.7	X		X	X
8	Electronic Signatures	4.2.8	C.1.8		X	X	X
9	Performance Metrics Based on Actual Data	4.2.9	C.1.9			X	
10	User Technical Information Presentation System	4.2.10	C.1.10	X	X	X	X
11	Preplanned Over & Above/Unpredictables	4.2.11	C.1.11	X		X	
12	Planning Responsibility Centers	4.2.12	C.1.12	X			
13	Automated and Integrated Technical and Diagnostics Information	4.2.13	C.1.13				X
14	Multi-skilled Mechanics	4.2.14	C.1.14			X	
15	Three Shifts	N/A	C.1.15				

* Abbreviations for *ITI-ALC Architecture Report, Business Case,* Work Package test, and Troubleshooting demonstration.

3.7.4 Demonstration/Evaluation Plan Possible Recommendations and Lessons Learned

The following observations were made as suggestions to improving the results and efficiency of future efforts of this nature.

- **The title of the resulting document for this effort should have been; Experiment Design Document for the Demonstration of the Efficacy of the ITI-ALC System and BPIs.**

  It was obvious from ITI-ALC's Statement of Work (SOW) that AL/HRGO wanted a plan for an experiment that demonstrates the improved effectiveness and efficiency of mechanics and other depot PDM personnel when using new processes and technologies described in the *System/Segment Specification* and the *ITI-ALC Business Case.* This intent was not obvious from the title of the document per the CDRL list. A "demonstration" denotes a certain informal approach to the effort and a "test" would most likely be confused with a "System Test" which has a different intent (the intent of all formal system/software testing is to find errors in the system/software [Rubey86]) then what will be done for Phase II of ITI-ALC. In the future, AL/HRGO should name similar efforts as "Experiments".

- **Adjust the development schedule for the Demostration Plan.**

  Before time and resources are spent on designing an experiment, customer resources should be allocated to the review, analysis, understanding and critiquing of the results of that effort.

If another such program is conducted in the future, AL/HRGO should consider removing this tasks from the Phase I SOW due to it's premature nature. This task is better suited to a time closer to the actual implementation of the plan.

- **Cost consideration for the experiment should be included.**

The test or demonstrations identified in the deliverable for this effort did not presume to evaluate the cost of performing the tasks identified in the experiment or the cost of building a demonstration system to conduct those tasks. However, the design was developed so that one half of the experiment could be conducted with little of no interaction with the second half, therefore allowing for a truncated test/demonstration. Another way to do this would be to get potential users involved much earlier (e.g., at the second release of the SSS) in the process to define which functional requirements they would like to see in a test/demonstration. This information would then have to be made available to the contractor performing the experiment design effort.

- **More emphases on functional demonstration verses system interface.**

To ensure a cost effective demonstration, more emphases should be put on prototyping the functional capabilities of the ITI-ALC system verses making something that will evolve into a production system. One aspect of "production level" software is that too much time/resources are spent in building "real" system-to-system interfaces with legacy and emerging system. Most of the data obtained from the supporting system included in the ITI-ALC design can be simulated/derived, allowing for more resources devoted to building a system that helps the user understand the ITI-ALC BPI concepts and that is flexible enough to try many different ideas. The industries trend toward "evolutionary" prototypes is an unrealized potential because the nature of prototypes and the nature of "production" software are mostly mutually exclusive. This lesson highlights and utilizes the flexibility and modularity of the ITI-ALC design per the SSDD and the SM.

4. CONCLUSIONS AND RECOMMENDATIONS

The ITI-ALC program was performed to develop the requirements for a more efficient, streamlined organic PDM process by using a two step BPR approach. The first set was to document and analyze the current process. Through this analysis, the process was streamlined, the informational requirements to support the process was refined, the organizational responsibilities for the process segments was revised, and the regulation modifications needed to support the streamlined process were identified. The second set was to develop the requirements for computerized ITI-ALC system that will effectively support the implementation of the streamlined PDM process. This section summarizes, as required by the DID referenced by the SOW, the discussion and recommendations presented in this report.

The ITI-ALC BPR analysis program was effectively and efficiently performed through the use of SRA's user-focused, structured BPR methodology implemented using a proven set of integrated tools and techniques. This methodology ensured a high probability of success because it established an integrated team consisting of SRA team members, functional experts, HRGO program personnel, and users from each of the five ALCs. Specifically, this methodology focused on the PDM process from the user's perspective, thereby ensuring that user problems were identified and that the resulting improvement concepts addressed the user problems, were practical, were accepted by the users, and were incorporated into the requirements for the ITI-ALC system and traceable back to the user requirements

The users that were actively involved in the performance of the ITI-ALC program represented all aspects the depot maintenance process contained within the scope defined for the program, represented all five of the ALCs, and represented the maintenance process used to maintain a variety of systems and aircraft type. From each ALC, the users included planners, schedulers, aircraft managers, and mechanics, as well as a variety of individuals responsible for activities that interface with these primary users, such as supply. The items used as the select set for the analysis included a combination of light and heavy aircraft as well as engines. Specifically, included were the F-16, F-15, F-22, C-135, and C-5 aircraft; and the F110 and F100 engines. Within these items, those maintenance processes on which the analysis was specifically directed were for the EF-111 Tactical Jamming System, LANTIRN, Advanced Composites, Landing Gear, Fuel Controls, Constant Speed Drives, and Generators.

Figure 4-1 provides an overview of the methodology used to perform the PDM process analysis. This methodology was developed over a period of fifteen years by SRA team members, is well documented in a number of published papers and case studies, and has been successfully applied on a number of BPR efforts. While we have used this methodology successfully to improve processes, we view the methodology and the associated techniques and tools as an evolutionary process. Therefore, as part of each application, we analyze and refine the methodology, techniques, and tools based on the possible recommendations and/or lessons learned from each application. Using this approach to process improvement analysis, we are continually increasing the probability of success for each BPR analysis effort.

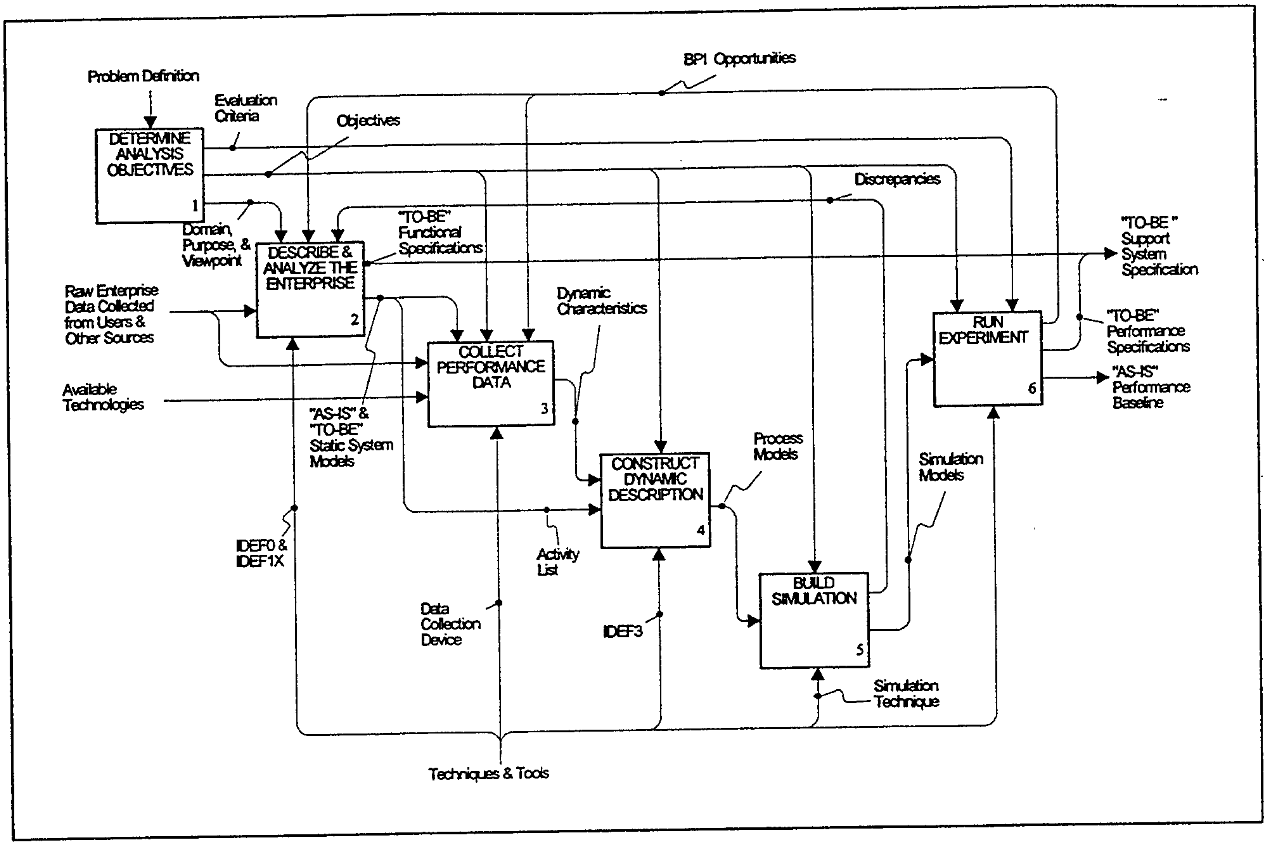


Figure 4-1. The Enterprise Representation and Analysis Process

While reading this discussion of the methodology, it is important to understand that the models developed through the application of this methodology are not final products, but rather are critical analysis tools that provide the foundation needed for understanding, documenting and analyzing the depot maintenance process. Through the analysis of the models are generated the accurate and complete SSS and SSDD needed to take the next step of design, developing, and implementing the improved process and the ITI-ALC system.

The BPR improvement methodology begins with the definition of the problem to be addressed. This definition defines the enterprise to be examined and the improvement goals to be achieved. The problem definition is analyzed to establish the specific domain of the enterprise to be analyzed, the purpose and viewpoint around which the enterprise is to be analyzed, the objectives of the Business Process Reengineering effort, and the evaluation criteria to be used in judging the effectiveness of the BPIs.

The domain, purpose, and viewpoint of the enterprise then guide the development of a set "AS-IS" models that provide a static description of the process from functional, data, and cost perspectives. The initial development of these models help to establish and scope the type of data needed to describe the enterprise, to identify the sources for the data, to collect the data, and to organize and access the data. These sources may include functional area experts, users, enterprise documentation, etc. These collected data are used to refine and expand the "AS-IS" models into a complete and accurate description of the current process.

To complete the BPR analysis also requires the analysis of the process from a performance perspective. This perspective is developed by using the "AS-IS" functional model as the basis for identifying and collecting process performance information, developing a process flow modeling onto which is overlaid the performance information to produce a simulation which can then be exercised to assist in the verification and validation of the "AS-IS" model set, and to analyze the performance of the current process. At a minimum, these dynamic characteristics include functional timing specifications and the process flow through the enterprise.

Through the analysis of the "AS-IS" functional, data, cost, and performance models improvement concepts are identified and documented using a corresponding set of "TO-BE" models. When completed, the "TO-BE" models provide the foundation for developing the description for the ITI-ALC system that will support the implementation of the improved process as documented in the "TO-BE" model set. The description of the ITI-ALC system begins by extracting the requirements from the "TO-BE" models and documented them in the SSS. A high-level operational design for the ITI-ALC system is developed by developing a system model which describes how the various proposed functional components the ITI-ALC system will interact to share data throughout the performance of the depot maintenance process. This proposed operational concept is then documented in the SSDD.

Resulting from the methodology, therefore are a set of "AS-IS" and "TO-BE" models, and specifications for the improved process and for the ITI-ALC system documented via the system model, the SSS, and the SSDD. These specifications provide the information foundation that will be required during the design and development phase.

An integrated set of techniques, supported by automated tools, was applied to effectively implement the methodology, The specific products, and the techniques used to develop the products, are summarized as follows:

Functional Models (FMs) – IDEF$_0$

"AS-IS" - Represents the current depot maintenance activities.

"TO-BE" - Represents the recommended or future depot maintenance activities.

Data Models (DMs) – IDEF$_{1x}$

"AS-IS" - Represents the logical information structure that supports the current depot maintenance process.

"TO-BE" - Represents the recommended logical information structure to support the future depot maintenance process.

Process Models (PM) – IDEF$_3$

"AS-IS" - Represents the dynamic aspects of the current depot maintenance activities as defined by the "AS-IS" FM.

"TO-BE" - Represents the dynamic aspects of the recommended or future depot maintenance activities as defined by the "TO-BE" FM.

Simulation Models – **WITNESS**

Once developed, the $IDEF_3$ models were exercised to represent the operational characteristics of the PDM process. Specifically, the simulation models provided the following:

"AS-IS" - Represents the performance aspects of the current PDM process as defined in the "AS-IS" functional model.

"TO-BE" - Represents the performance aspects of the recommended or future PDM process as defined by the "TO-BE" FM.

System Model (SM) – **Data Flow Diagrams**

Defines an operational concept for the ITI-ALC system and provides transition from the requirements definition phase to the design and development phases.

Business Case (BC) – **CDRL A002**

- Documents the cost/benefit analysis for the "TO-BE" implementation.

System/Segment Specification (SSS) – **CDRL A008**

- Documents the requirements for the retool needed in the "TO-BE" implementation.

System/Segment Design Document (SSDD) – **CDRL A014**

- High-level design for the "TO-BE" implementation.

IMIS/ITI-ALC System Comparison – **CDRL A011**

- Functional comparison between the IMIS and ITI-ALC system, and a demonstration plan for the next phase of ITI-ALC.

Demonstration Plan – **CDRL A012**

- Planning document for a Phase II demonstration of the ITI-ALC system.

As represented in Figure 4-2, the development of the various "AS-IS" and "TO-BE" models, the system model, the business case, the SSS, the SSDD were developed in an iterative manner with the users providing key participation throughout the program. This ensured consistency and completeness among the various models and documents, and ensured the tractability of information all the way from the users, through the various models, and into the SSS and SSDD.

The problem definition provided the basis for the development of the "AS-IS" models which were validated with the users. Through the analysis of these models, process improvement opportunities were identified and used, along with improvement ideas provided by the users, to refine the "AS-IS" models into the "TO-BE" models representing the streamlined process. The "TO-BE" models and improvement concepts were presented to the users to gain their understanding, review, comments, and acceptance.

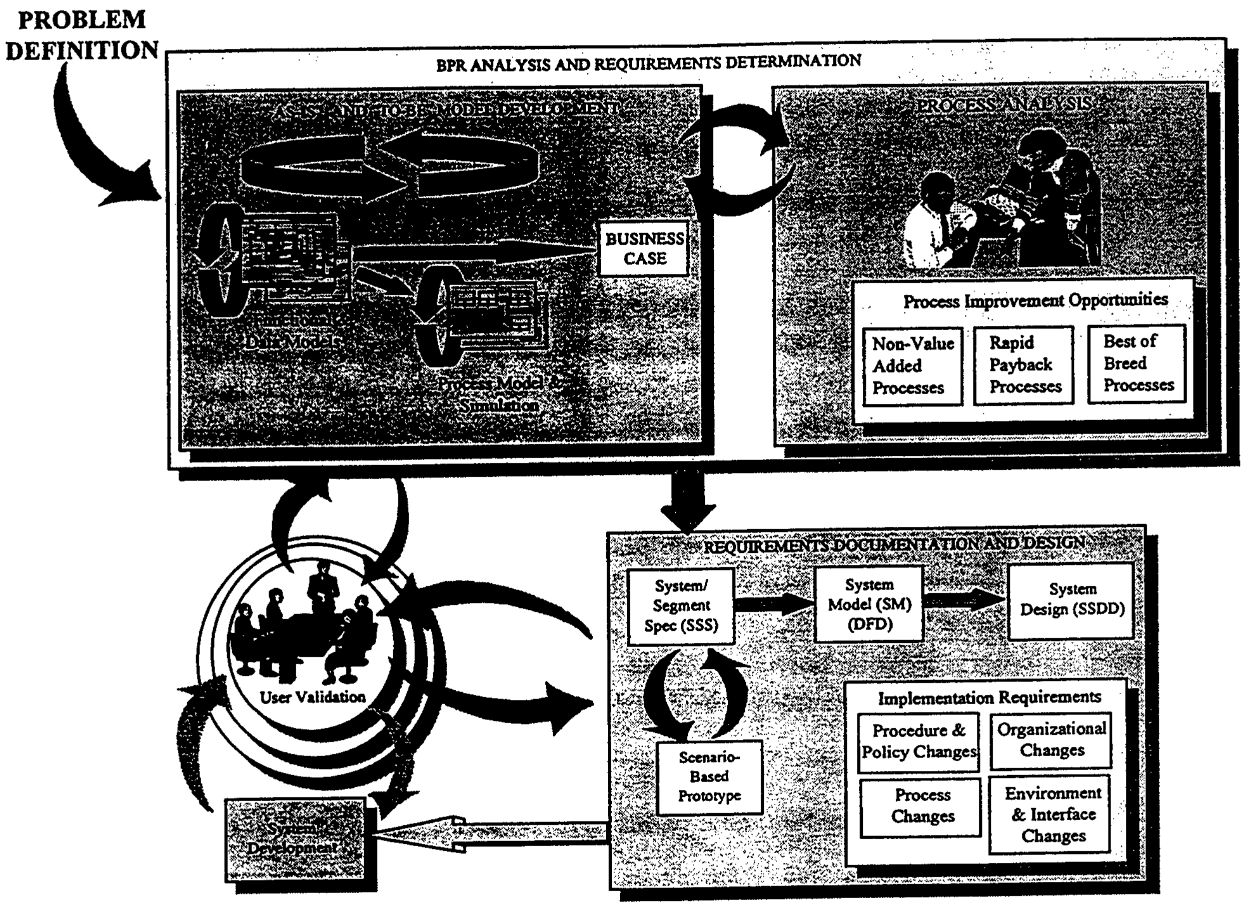


Figure 4-2. The BPR Analysis Methodology is User Focused

When completed, the "TO-BE" models provided the basis for documenting the requirements as represented in the models and to begin an initial implementation design of the improved process and ITI-ALC system. The implementation of the improvement concepts had to satisfy implementation requirements consisting of changes in processes, policies and procedures, organizations, and environment and interface changes. As with the models and improvement opportunities, the documented requirements and initial design were validated with the government personnel and users.

The users involvement ensured the overall BPR analysis effort maintained its user focus and ensured user acceptance and therefore success of the ITI-ALC program. The roles played by the users are summarized as follows:

1. Provided information about the maintenance process from each of their perspectives and was used as the starting point for understanding and documenting the current process.

2. Provide their perspectives about the problems that exists within the current process and for improvement ideas that could help the operational effectiveness of the current process.

3. Reviewed the "AS-IS" models to ensure that a complete and accurate foundation had been developed on which to build the analysis effort.

4. Reviewed, refined, and commented on the improvement concepts as they were being formalized to ensure they would help the users and would provide practical benefits.

5. Reviewed and commented of the "TO-BE" models to ensure that required process functionality had not been lost or that unnecessary functionality had been added.

6. Reviewed the SM to verify that the operational concept presented in the SM satisfied the operational goals of the maintenance personnel.

7. Reviewed the SSS to ensure that the requirements were complete, accurate, and stated in a manner that was understandable to the maintenance community.

While the ITI-ALC program requirements were satisfied with the development of the SSS and SSDD, the next phase in the overall ITI-ALC program is the completion of the design, followed by the development and implementation of the improved process and the ITI-ALC system. The user-focused information developed thus far will provide a solid foundation on which to perform the next phase. Reasons for the solid foundation are the following:

1. The users have been identified.

2. The users are fully aware of and have accepted the concepts that are to be implemented.

3. Specific user problems are being addressed.

4. A complete set of requirements exist to guide the design and development.

Using this approach reduces the possibility that the system designer will under or over specify the support system. Under-specifying the support system will reduce user acceptance of the system; whereas over-specifying will likely increase the cost of the implementation, and reduce utilization of the support systems. Through the accurate specifications for the support system, a good correlation between the processing requirements and the technology capabilities can be derived, resulting in an efficient, more cost effective enterprise.

In conclusion, the method used to fulfill the ITI-ALC Phase I requirements, although not perfect (as indicated be the numerous recommendations and/or lessons learned throughout this report), is a very efficient and effective process to perform BPR. It is recommended that the items identified as lessons be phased into the baseline process over several programs based on metrics focused benefit/cost analysis of each of the improvements. Appendix B lists the possible recommendations and/or lessons learned organized by project entity (e.g., FM, DM, SSS, SSDD, and so forth). The newest "golden bullets" although exciting, are always accompanied by high risk, rework and cost -- revolution is seldom without pain. Given this, steady, well planned evolution based on experience and a balance between new and old ideas is preferred unless customer expectations are equal to the reality of the revolutionary process.

5. REFERENCES

This section lists reference citations that are used within this document. The list of references below are alphabetically arranged.

- *CIM Technical Reference Model*, Version 1.2, May 15, 1992.
- DoD 8320.1-M-1, *DoD Data Element Standardization Procedures*, January 1993, authorized by DoD Directive 8320.1, September 26, 1991.
- DoD TAFIM, Volume 1, *Overview*, Version 2.0, June 30, 1994.
- DoD TAFIM, Volume 2, *Technical Reference Model and Standards Profile Summary*, Version 2.0, June 30, 1994.
- DoD TAFIM, Volume 3, *Architecture Concepts and Design Guidance*, Version 2.0, June 30, 1994.
- DoD TAFIM, Volume 4, *DoD Standards-Based Architecture Planning Guide*, Version 2.0, June 30, 1994.
- DoD TAFIM, Volume 6, *DoD Goal Security Architecture*, Version 2.0, June 30, 1994.
- DoD TAFIM, Volume 8, *DoD HCL Style Guide*, Version 2.0, June 30, 1994.
- FIPS Publication 161, *Electronic Data Interchange (EDI)*, April 19, 1993.
- FIPS Publication 179, *NIST Government Network Management Profile (GNMP) Draft*, December, 1992.
- FIPS Publication 183, *Integration Definition for Function Modeling (IDEF0)*, December 21, 1993.
- FIPS Publication 184, *Integration Definition for Information Modeling (IDEF1X)*, December 21, 1993.
- GAO-GGD-94-154, *Proposed Policy to Accept Credit and Debit Cards Make Sense Conceptually,* Arthur D. Little, 1994.
- GAO/AFMD-92-12, *Financial Audit: Aggressive Actions Needed for Air Force to meet Objectives of the CFO Act*, 1992.
- GAO/NSIAD-91-176, *Defense Inventory: Shortcomings in Requirements Determination Processes,* 1991.

- IICE, *IDEF$_3$ Process Description Capture Method Report,* May 1992.
- IMIS, *Final Scientific and Technical Report of the IMIS Architecture*, General Dynamic Electronics Division/SofTech Inc., 30 May 1990.
- ITI-ALC, *Final Architecture Report,* Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A007, 29 June 1995.
- ITI-ALC, *Business Case -- Final Submittal,* Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A002, 29 March 1996.
- ITI-ALC, *Depot Requirements Compared to Prototype Capability*, Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A011, 19 December 1995.
- ITI-ALC, *Demonstration/Evaluation Plan,* Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A010, 19 December 1995.
- ITI-ALC, *System/Segment Design Document -- Final,* Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A014, 15 February 1996.
- ITI-ALC, *System/Segment Specification -- Final,* Systems Research and Applications Corporation, Contract No. F41624-94-C-5021, CDRL No. A008, 31 October 1995.
- JLSC's *Improved Functional Baseline (IFB) IDEF0 Model and Glossary,* October 1993, Revised July 1994.
- JLSC's *Improved Functional Baseline (IFB) IDEF1x Model and Glossary (key-based) Technical Report,* February 1994.
- MIL-D-87269, Military Specification, *Data Base, Revisable: Interactive Electronic Technical Manuals, for the Support Of,* 20 November 1992.
- MR-313-A/USN, RAND, *An Approach to Understanding the Value of Parts,* April 1991.
- *Strategy and Structure,* A. D. Chandler, Cambridge Mass, MIT Press, 1992.
- *The DoD Enterprise Model, Volume I: Strategic Activity and Data Models*, January 1994.
- *The DoD Enterprise Model, Volume II: Using the DoD Enterprise Model - A Strategic View of Change in DoD* - A White Paper, January 1994.

APPENDIX A. MODEL DOCUMENTATION

The significant information contained in the models and the resources invested in the various models required they be effectively documented for use on the ITI-ALC program as well as references on future programs. These models, and their associated information were documented in the Appendices of the ITI-ALC Architecture Report as follows:

APPENDIX	CONTEXT
A	"AS-IS" Functional Model
B	"AS-IS" Data Model
C	"AS-IS" Data Glossary (For the Functional and Data "AS-IS" models)
D	"TO-BE" Functional Model
E	"TO-BE" Data Model
F	"TO-BE" Data Glossary (For the Functional and Data "TO-BE" models)
G	System Model
H	System Model Glossary
I	"AS-IS" Process Model
J	"TO-BE" Process Model
K	"AS-IS" Functional Model to Interview Traceability Matrix
L	"AS-IS" Data Model to "AS-IS" Functional Model Traceability Matrix
M	"TO-BE" to "AS-IS" Functional Model Traceability Matrix
N	"TO-BE" Data Model to Functional Model Traceability Matrix
O	System Model to "TO-BE" Functional Model Traceability Matrix
P	"TO-BE" Functional Model to the IMIS "TO-BE" Control Architecture Traceability Matrix
Q	Interview Kit used during the Data Collection Trips

The development of each of these appendices was accomplished using automated techniques. The automated documentation development approaches ensured the completeness and accuracy of each appendix, reduced the level of resources needed to produce the document, ensured the consistent and high visual quality of the document, and allowed for the flexibility of incorporation of any model refinement up to the last minute.

A.1 FUNCTIONAL MODEL (FM) DOCUMENTATION

The documentation procedure for the "AS-IS" and "TO-BE" functional models, developed using Design/IDEF, is represented in Figure A-1. The node list was developed by processing the activity report produced by Design/IDEF.

The page-pair format of the functional model was developed by aggregating the model diagrams obtained from Design/IDEF and the associated narrative text obtained from a word processor. To accomplish this, the structure of the model was used to set up the page-pair format. Then the diagram graphics from Design/IDEF were inserted into the appropriate locations, and the narrative text was inserted to complete the page-pair documentation, as contained in Appendices A and D.

To complete the documentation of the functional models required the development of their respective glossaries. A list of all the arrow names, their diagram references, and a listing of all arrow definitions were extracted from Design/IDEF. These three sets of information were then merged to form the functional model portion of the glossaries documented in Appendices C and F.

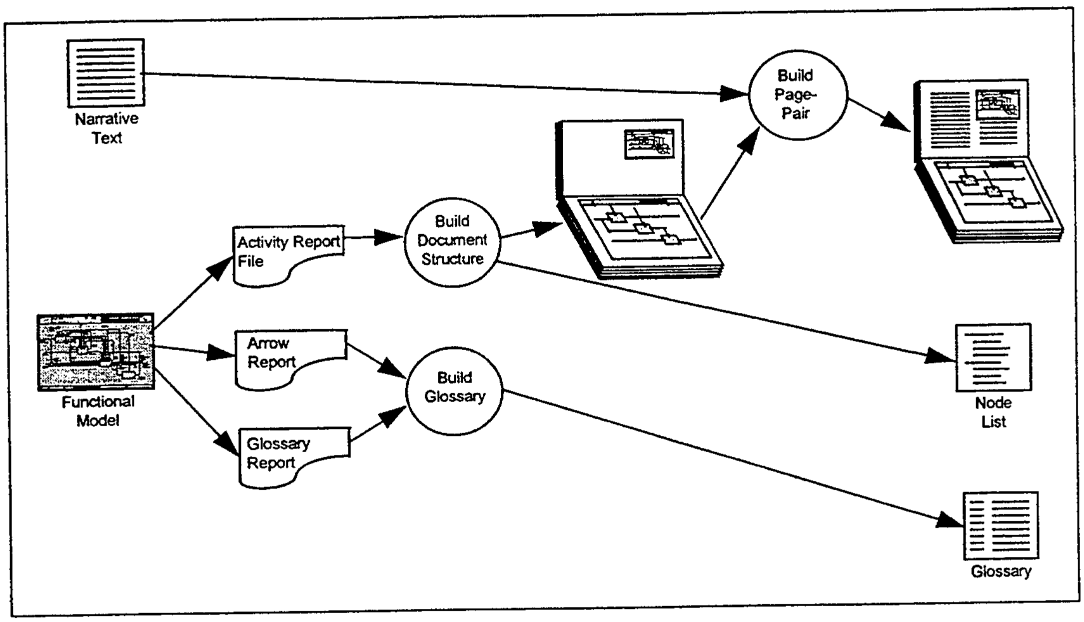


Figure A-1. The FM Documentation Procedure

A.2 DATA MODEL (DM) DOCUMENTATION

The documentation of the data models presented a significant challenge. A complete data model for a process such as the depot maintenance is larger than can effectively be displayed. Also, the entity diagram approach used on other programs has not proved to be an effective documentation technique because it is too restrictive of the information available to the reader/analyst at any point in time.

To improve the effectiveness of the data model documentation, subject areas or views into the complete data model were selected and presented in a page-pair format to augment a foldout of the entire model. These subject areas limited the amount of information so that it could be effectively displayed on an 8.5” x 11” page but included a grouping of information that described a particular aspect of the process.

To facilitate the selection and documentation of these views required the use of computerized capabilities. While the final documentation of the "AS-IS" and "TO-BE" data models have the same appearance, the tools used to develop each of the models were different. As a result, the procedures for developing the final documentation for each of the models were slightly different and are described in the following paragraphs.

A.2.1 Documentation of the "AS-IS" Data Model

The "AS-IS" data model was developed using Design/IDEF and Figure A-2 represents the documentation process that was applied. The views into the data model were identified and then extracted from the completed model through the processing of the SML report. The extracted subject area SML was then processed through Design/IDEF and inserted into the appropriate location within the page-pair document. The narrative description for each view was then developed and added to complete the page-pair documentation of the "AS-IS" data model. This page-pair document was placed in Appendix B of the Architecture Report.

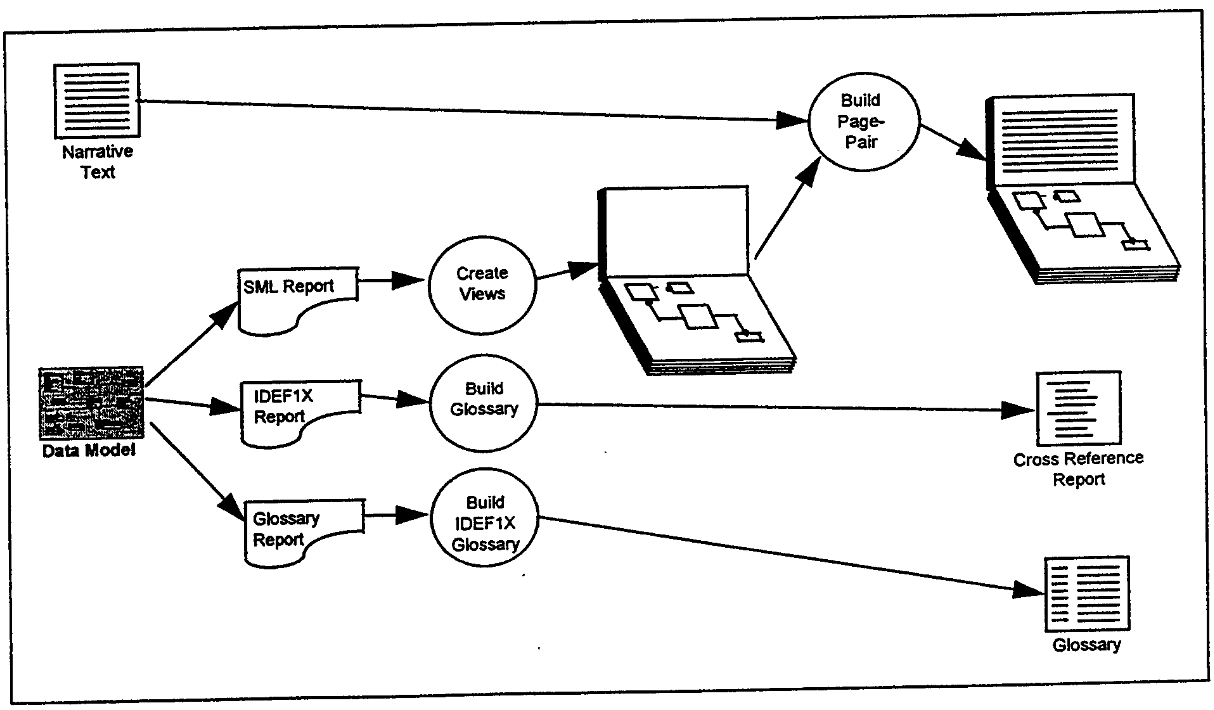


Figure A-2. The "AS-IS" DM Documentation Procedure

To facilitate locating entities within the various subject diagrams and to help ensure that all entities had been included in at least one view, a cross reference report was developed. This report was developed by processing the IDEF$_{1X}$ report generated by Design/IDEF and was placed in Appendix B.

The glossary was developed to identify and define each entity and attribute within the "AS-IS" data model. The glossary was developed by processing the glossary report produced by Design/IDEF. This glossary was then merged with the glossary for the "AS-IS" functional model to complete the development of Appendix C within the Architecture Report.

A.2.2 Documentation of the "TO-BE" Data Model

While the capabilities of Design/IDEF to support the "AS-IS" data modeling were adequate, an analysis of the ERWin tool demonstrated that it had key benefits over the data modeling aspects of Design/IDEF. Specifically, ERWin provided improved of attributes among the entities to better support the implementation of the $IDEF_{1X}$ notation. ERWin also facilitated the development of the glossary and was effective in pulling out the subjects areas identified for model documentation. Therefore, ERWin was selected for use in developing the "TO-BE" data model.

Because of the limited graphics control provide by ERWin, the completed model was transferred from ERWin into Design/IDEF where the model layout was adjusted to provide the quality needed for the Architecture Report.

A.3 PROCESS MODEL (PM) DOCUMENTATION

The documentation of the process model is made of two components which are contained in Appendices I and J for the "AS-IS" and "TO-BE" models, respectively. These components are the diagrams and the activity performance information. The flow of information into the Architecture Report and the structure of these appendices are represented in Figure A-3.

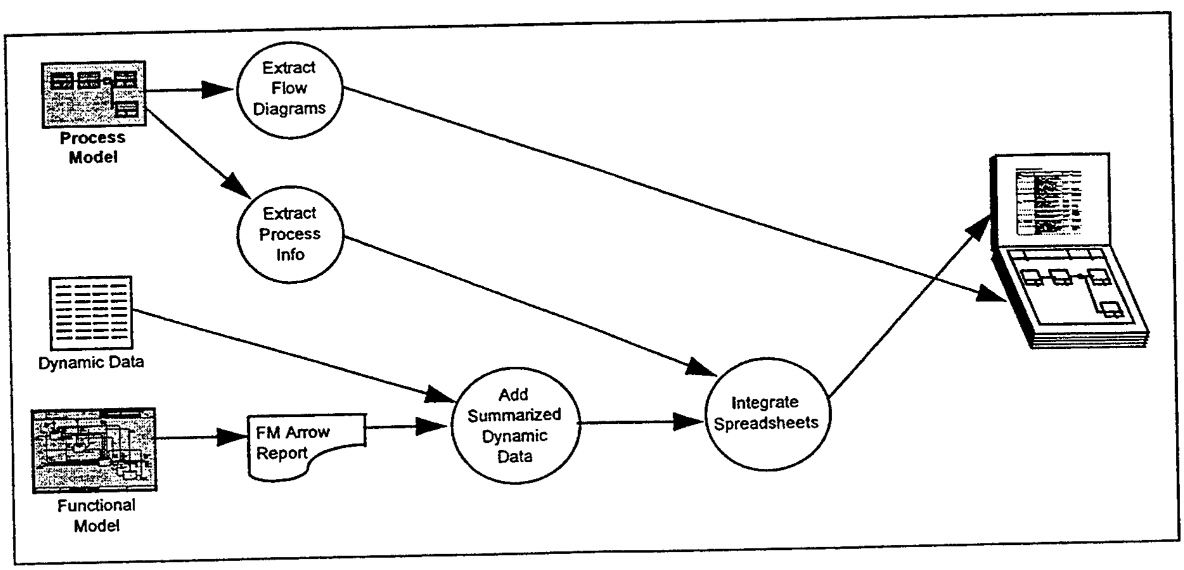


Figure A-3. The PM Documentation Process

A.4 SYSTEM MODEL (SM) DOCUMENTATION

The system model, which addresses the design of the ITI-ALC depot maintenance system, was developed using System Architecture. The model was developed using data flow diagrams which are hierarchical in nature much like the $IDEF_0$ model. Therefore the page-pair format consisting of the diagrams and associated text was chosen for the SM. This page-pair format is then supplemented with a node list and glossary. The procedure for developing the SM documentation is represented in Figure A-4.

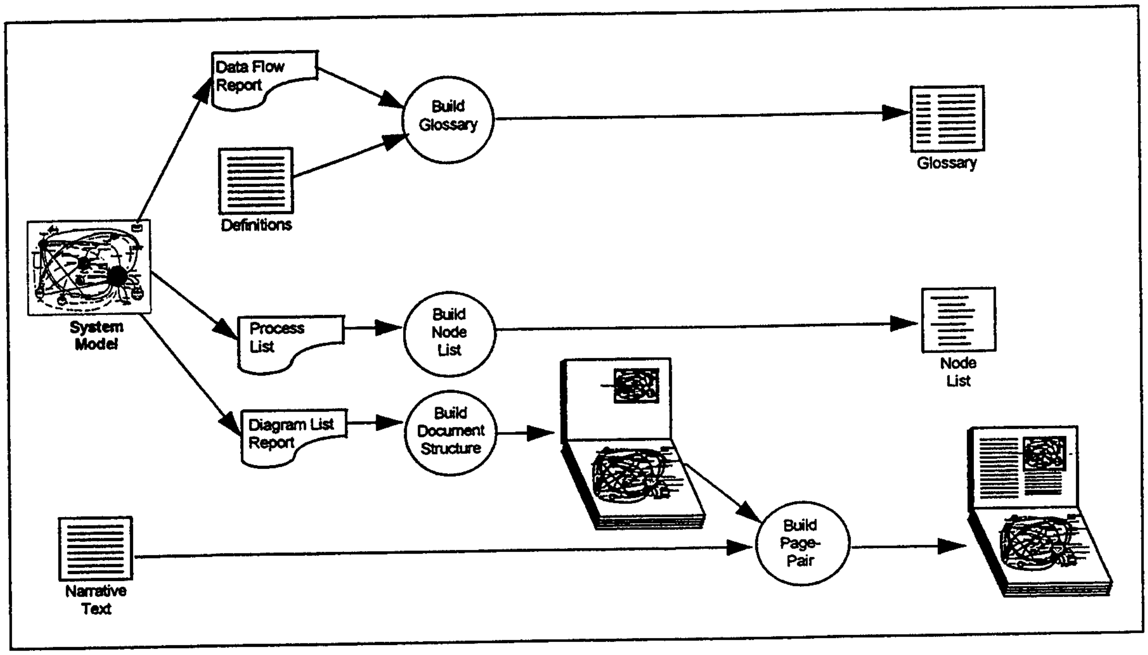


Figure A-4. The SM Documentation Process

A customized set of report generators were developed to select and transfer information from System Architecture into an ASCII file for documenting the SM. One of these reports was used to establish the page-pair format for the report. The diagrams from System Architecture were extracted and inserted into the page-pair structure. The narrative for each diagram was then inserted to complete the page-pair format of the SM as contained in Appendix G of the System Architecture.

Another customized report extracted the process list from System Architecture and processed to produce the node list for the system model. This node list is located in front of the model in Appendix G.

The final step in documenting the system model was the generation of the glossary for the data flows. The names of the data flows were extracted from System Architecture by a customized report and definitions added to the flow names. The definitions and the data flow names were then formatted into the glossary as documented in Appendix H of the Architecture Report.

APPENDIX B. ACRONYM/ABBREVIATION LIST

This appendix lists the acronyms and/or abbreviations included in this document.

Acronym Abbreviation	**Definition**
A/C	Aircraft
AFLC	Air Force Logistics Command
AFMC	Air Force Materiel Command
AFTO	Air Force Technical Order
AHP	Analytic Hierarchy Process
AIS	Automated Information System
ALC	Air Logistics Center
AL/HRGO	Armstrong Laboratory/Logistics Research Division, Operational Logistics Branch
ANOVA	Analysis of Variance
APDS	Automatic Parts Distribution System
ASRS	Automated Storage and Retrieval System
BOM	Bill of Materials
BPI	Business Process Improvement
BPR	Business Process Reengineering
CALS	Continuous Acquisition and Life-Cycle Support
CAMS	Core Automated Maintenance System
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CEMS	Comprehensive Engineering Management System
CIM	Corporate Information Management
CMM	Capability Maturity Model
COTS	Commercial-off-the-Shelf
CSC	Computer Software Component
D-level	Depot level
DFD	Data Flow Diagram
DM	Data Model
DM-HMMS	Depot Maintenance-Hazardous Material Management System

Acronym Abbreviation	**Definition**
DMMIS	Depot Maintenance Management Information System
DMSS	Depot Maintenance Standard System
DoD	Department of Defense
ESD	End-Item Status Display
FCA	Functional Configuration Audit
FEMS	Facility Equipment Management System
FIPS	Federal Information Processing Standards
FM	Functional Model
FSS	Financial Standard System
HAZMAT	Hazardous Material
HW	Hardware
HMSS	Hazardous Material Standard System
HWCI	Hardware Configuration Item
ICD	Interface Control Document
ICN	ITI-ALC Communication Network
IDEF	Integrated DEFinition
IETM	Interactive Electronic Technical Manuals
I/F	Interface
I-level	Intermediate level
IMDS	Integrated Maintenance Data System
IMIS	Integrated Maintenance Information System
ISD	ITI-ALC Server Device
ISN	ITI-ALC Server Network
ITI-ALC	Integrated Technical Information for the Air Logistics Centers
IWD	ITI-ALC Workstation Device
JCALS	Joint Continuous Acquisition and Life-Cycle Support
JLSC	Joint Logistics Systems Center
LAN	Local Area Network
MDC	Maintenance Data Collection
MDS	Mission, Design, and Series

Acronym Abbreviation	**Definition**
MMD	Mobile Management Device
MMSS	Materiel Management Standard System
MOA	Memorandum of Agreement
MRRB	Maintenance Requirement Review Board
MSD	Maintenance Support Device
MWN	Maintenance Wireless Network
O-level	Organizational level
OC-ALC	Oklahoma City-Air Logistics Center
OO-ALC	Ogden-Air Logistics Center
OSD	Organization Status Display
PAC	Production Acceptance Certification System
PCA	Physical Configuration Audit
PDM	Programmed Depot Maintenance
PDMSS	Programmed Depot Maintenance Scheduling System
PERT	Program Evaluation Review Technique
PIP	Process Improvement Proposal
PM	Process Model
PWPS	Project Workload Planning System
QA	Quality Assurance
QAP	Quality Assurance Plan
QAO	Quality Assurance Officer (for ITI-ALC: Dr. Walt Seward)
RCSD	Responsibility Center Status Display
REMIS	Reliability and Maintainability Information System
REQ	Requirement
RTC	Requirements Traceability Component
SA-ALC	San Antonio-Air Logistics Center
SDR	System Design Review
SEI	Software Engineering Institute
S&IO	Support and Industrial Operations
SM	System Model

Acronym Abbreviation	Definition
SM-ALC	Sacramento-Air Logistics Center
SOW	Statement of Work
SQL	Structured Query Language
SRA	Systems Research and Applications
SSR	Software Specification Review
SSDD	System/Segment Design Document
SSS	System/Segment Specification
SW	Software
TAFIM	Technical Architecture Framework for Information Management
TIMA	Tool Inventory and Management Application
TLSP	Transport Layer Security Protocol
TO	Technical Order
TODO	Technical Order Distribution Office
TRR	Test Readiness Review
VAF	Value Adjustment Factor
WBS	Work Breakdown Structure
WCD	Work Control Document
WPAFB	Wright-Patterson Air Force Base
WR-ALC	Warner Robins-Air Logistics Center
WSD	Work Status Device

APPENDIX C. SUMMARY OF POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED

C.1 GENERAL PROJECT (REF.; SECTION 1.0)

Important issues to be considered for all or most of the project.

- **Significant preparation for the data collection trips is critical.**

  User acceptance is critical to any system development effort. Because the data collection trips were the first technical interface with the users and because humans have a tendency to let "first impressions be lasting impressions," the data collection trips provided the first and best opportunity to gain the users' acceptance of and involvement in the ITI-ALC program. The data collection trips were well planned as determined by the positive feedback and involvement received from the ALC personnel.

- **The model development order must be such that the benefits of their integration is fully utilized.**

  The methodology applied to the ITI-ALC program was based on the development and analysis of an integrated set of models and reports documenting the requirements, specifications, design, and benefits predicted from implementing the improved process and the ITI-ALC system. The models developed for this methodology were the following:

  - "AS-IS" and "TO-BE" Functional Models,
  - "AS-IS" and "TO-BE" Data Models,
  - "AS-IS" and "TO-BE" Process Models,
  - "AS-IS" and "TO-BE" Simulation Models, and
  - System Model.

  The reports developed were the ITI-ALC Business Case, System/Segment Specification (SSS), and the System/Segment Design Document (SSDD). The development order of these items was good, but minor adjustments would have improved the effective performance of the ITI-ALC program. Of specific importance was the development and analysis of the process flow and simulation models. Having established the requirements for these models and analyses earlier in the program would have reduced some of the duplicative data collection efforts.

- **Validation difficulty varied among the various artifacts developed.**

  The various "AS-IS" and "TO-BE" models, which formed the foundation for the program, required significant time and effort for validation by the functional experts and users. These validation efforts were implemented using the readership cycle and on-site walkthroughs. While the review results were sufficient for validation, the validation of the SSS handled as a workshop away from the ALC worksite proved to be more productive. Therefore, the use of similar workshops for the "AS-IS" and "TO-BE" models would be recommended.

- **Data flow diagrams are an excellent way to represent the system model.**

  The top-down approach supported by data flow diagrams provided gradual, controlled concept of operation for the ITI-ALC system. This approach also provided a direct link of information from the functional and data models, thereby, supporting the requirement for the traceability of information through the models. While the concept of using data flow diagrams was effective, the System Architecture tool used to developed these diagrams had some short comings that need to be corrected to support data flow diagram development.

- **The concept of developing and using process flow diagrams via the Integrated DEFinition (IDEF$_3$) notation and simulation via WITNESS was value added to the overall ITI-ALC program.**

  The development of the process flow diagrams was facilitated by the existence of the functional models while the development of the process flow models helped to increase the accuracy and completeness of the functional models. The process model provided an effective structure to identify and collect the performance information required from simulation and provided an effective structure for developing and depicting the simulations.

- **The tools used to implement the process flow model and the translation to simulation are not yet mature.**

  The translation capability from ProSim™ to WITNESS® was not complete. The transfer from ProSim to WITNESS required a significant amount of data addition and manipulation in WITNESS before the process flow could be exercised using WITNESS. During the ITI-ALC program, this ineffective transfer of information was overcome by developing an in-depth understanding of the transfer requirements and accomplishing much of it manually.

  The translation from the process description to the simulation was one-directional. The intent of IDEF$_3$, as implemented via ProSim, is to collect process flow and performance information so as to facilitate the development and execution of a simulation model within WITNESS. However, because significant effort was required to complete the simulation model in WITNESS, the value of the IDEF$_3$ model via ProSim was significantly reduced once the first translation is accomplished. During the ITI-ALC program, this situation was addressed by maintaining the IDEF$_3$/ProSim representation for display of the network while adjusting the model within WITNESS as needed for the simulation.

  The process model notation, as represented by ProSim, was not an effective presentation vehicle for two reasons. First, the information presented on a process flow network was very limited, making it a labor intensive effort to read and analyze a process flow. Second, the amount of readable information printed on one page was limited, forcing the model to be developed in short segments. Connecting the short segments to form and effectively depict a larger process was difficult. This difficulty was reduced by using the functional model and performance data sheets to supplement the use of the process flow represented via ProSim.

- **An integrated team effort is required to maximize the quality of the BPIs and the products developed throughout the program.**

  Throughout the performance of the ITI-ALC program communication among the team members was important to ensure a unified understanding of the "AS-IS" and "TO-BE" depot maintenance processes, and was critical during the development of the System Model (SM), SSS, and SSDD. Even though the SM, SSS, and SSDD developments are based on the "TO-BE" models, the interpretation of the models can vary slightly, causing potential inconsistencies among these artifacts. Close interactions among the developers of all the program artifacts, and especially the SM, SSS, and SSDD maximized the effectiveness of the ITI-ALC system requirements, concept of operation, and high-level design.

C.2 "AS-IS" FM POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.1.1.4)

The following possible recommendations or lessons were learned during the data collection and the development and use of the "AS-IS" FM.

- **Significant preparation for the data collection trips was critical.**

  User acceptance is critical to any system development effort. Because the data collection trips were the first technical interface with the users and because humans have a tendency to let "first impressions be lasting impressions", the data collection trips provided the first and best opportunity to gain the users' acceptance of and involvement in the ITI-ALC program. To acquire the desired positive impression, the data collection trips must be well planned and effectively implemented.

  The data collection for the ITI-ALC program was effective. The strawman model provided a solid baseline for identifying the data to be collected, identifying the sources for the data, providing a good vehicle for training the interviewees about the process, and understanding where each interviewee fit into the depot maintenance process prior to starting an interview.

  The question set provided an effective means for supporting the data collection trips. While used only to a limited extent during the actual interviews, the primary value of the question set was in training the interviewers prior to the data collection trips. Much like the notes developed and used by an orator to prepare and practice the speech but used only as a quick reference during the delivery of the speech, the primary value of the question set was received during the preparation of the data collection effort.

- **Maintain a list of documents collected, user identified problems and improvement ideas, and a list of activities already defined.**

To implement an effective and efficient interview, each interview should confirm as well as build upon information from previous information. To support this information building process, an up-to-date list of key information should be maintained as reference and to reduce unnecessary effort.

A valuable source of information are documents, forms, etc. that are used within the process being described. Listing these documents, along with a short description of each provides an effective way of understanding what the interviewee is meaning when he indicates one of these documents and also provides a way of tracking which documents have already been requested or received.

In a similar manner, maintaining a list of process problems and solutions provided during previous intervals provided a guide to confirm the same ideas from multiple sources and to build upon the ideas presented.

A list of activities performed within the process was also maintained in the DCD as a point of reference. This list provides a means of learning the terminology, of mapping previous interview information with information currently being collected, and identifying similar functions identified by different terminology. Using this approach produces a controlled but not restricted list of standardized activity identifiers.

- **The data collection interview must be carefully controlled by the interviewer.**

Interview control must be balanced between strict control where the interviewee is answering very specific questions, and loose control where the interviewee is doing all the talking. Asking questions based very tightly on the question set tended to limit the information provided by the interviewee and assumed that the interviewer's prior understanding of the process was accurate because the interviewer was directing the information being obtained. Initiating the interview with "tell me what you do" does not focus the interviewee so they tend to ramble, hoping they say something that is of importance to the interviewer.

The most effective approach was to explain our current understanding of the depot maintenance process, describe the types of information desired, and then ask questions that focused the interviewees discussion around the information needed. It was the interviewers responsibility to evaluate the usefulness of the information being provided and determine when additional questions were needed to refocus the discussion to ensure that the data requirement of the question set were satisfied. By allowing the interviewee to describe the process in their terms reduced their need to adjust to an unfamiliar way of discussing their process. As a general rule of thumb, it was effective at 2 to 3 minute intervals to ask a refocusing question or provide some type of indication to the interviewee that appropriate information was being provided.

Scheduling the interview for the one-hour duration was sufficient to collect significant information and not lose the attention of the interviewee. To aid in accurately documenting the collected information, a one-hour period should also be scheduled immediately following the interview to formally record the information while it is still fresh.

- **An end-of-day meeting should be held during data collection trips.**

  The data collection teams should meet at the end of each day to review the events of the day and to distribute information among the team members. This review should address the individuals interviewed during the day, a summarization of the information obtained, identification of missing information, and a review of the reference list containing the documents collected, systems and activities identified, and process problems and improvement ideas. The schedule for the next set of interviews should also be reviewed and coordinated to ensure that each interview will be as productive as possible.

- **Allowing analysis time between data collection trips facilitates the collection of accurate and complete data.**

  Obtaining accurate and complete data requires that the interviewee and interviewer have the same interpretation of the questions being asked during data collection, that the interviewee is providing accurate information, and that the interviewer is interpreting the answers correctly.

  The best way to identify discrepancies in the collected data is to obtain and analyze information related to the same aspect of the process but from different sources. This analysis is facilitated by allowing sufficient time between the interview trips. This analysis verifies the process understanding by the interviewers, verifies consistency among the data, and identifies holes in the data.

- **Effective scoping of the functional model is important to maximize the benefits received from a BPR effort.**

  The focal point of the ITI-ALC program was the PDM mechanics within the Air Force's Air Logistics Centers. However, the scope was expanded at program initiation to include within the scope of ITI-ALC's BPR analysis the operational environments impacting the mechanic's performance effectiveness. This expanded scope provided the foundation needed to effectively streamline the mechanic process since much of the work performed by the mechanic was a duplication or continuation of the work performed by other individuals. Therefore, restricting the scope of the ITI-ALC program just to the mechanic would have limit the BPIs identified for the mechanic and would have reduced improved effectiveness provided by the proposed ITI-ALC system.

C.3 "AS-IS" DM POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.1.2.4)

The following possible recommendations and lessons were learned during the development and use of the "AS-IS" DM.

- **Developing the DM in conjunction with the FM resulted in a tight linkage between the models.**

  The original plan expected that modeling the functions performed would uncover many of the data requirements. However, we found that the data modeling also uncovered additional functional requirements. This two-way interchange could take place by walking through scenarios in the FM and identifying the information within the DM that supports the scenarios. Because of the tight linkage between the DM and the FM, the merging of the two glossaries was feasible and more useful than the presentation of individual glossaries.

- **The use of Design/IDEF as the IDEF$_{1X}$ modeling tool required some other conventions be adopted.**

  DoD 8320.1-M-1 mandates that a data element name consists of a prime word name with its modifiers and the generic element name with its modifiers. This convention was not adopted for two reasons. The tool automatically draws the entity boxes large enough to accommodate the largest entity or attribute name. Using fulling qualified names made the diagram much too crowded. Even using only the prime word name had to be relaxed because the tool requires that each attribute within the model be unique. So in some cases, the attribute name was concatenated on the entity name to form a unique attribute name. For example, more than one entity has an identifier attribute. To keep them unique, they became facility-identifier, cost-center-identifier, etc.

- **The data models could not be reviewed effectively as a whole.**

  The data models representing the "AS-IS" and "TO-BE" depot maintenance process were too large and complex to be effectively presented and reviewed as a single, complete model. To facilitate the reviews and and model discussions, the model was divided into subject areas, with each subject area containing groupings of related information. These subject areas were then same enough to support and effective and focused review. In addition, the subject areas also allowed for the use of an effective model documenation format. This format was a page-pair structure consisting of a subject area diagram and the associated text describing the diagram.

- **The normality rules had to be applied in a manner that maximized the development and usefulness of the "AS-IS" DM.**

  A primary objective of data modeling is to describe system data to the level where the data is completely normalized at the atomic level without duplication of null attribute values. While this is an optimal goal to strive for, a trade-off must sometimes be made between the optimal data model and a useful data model. For the ITI-ALC program, this optimized trade-off was defined by the following conditions.

1. The model would be developed to the 3rd normal form. The 5th normal form was not implemented since recursive relationships would be allowed unless additional attributes needed to be maintained in a resolving associative entity. The 4th normal form was not implemented to allow for the use of null attribute values. This avoided the creation of many category entities needed to eliminate null attributes but decreased the ease of understanding the data contained in the model.
2. Not all data was broken down to its atomic or normalized data elements. Trying to achieve all the atomic data elements involved significant effort but provided minimal benefit return. Also, representing the atomic data elements would significantly reduce the users' understanding of the model since they do not directly use or reference the atomic data elements.

C.4 "AS-IS" PM AND SIMULATIONS POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.1.3.4 & 3.2.3.4)

The requirement to use $IDEF_3$ and simulation analysis within the ITI-ALC program was (1) to provide a test case for using the $IDEF_3$ and simulation techniques, and (2) to evaluate and use these performance analysis capabilities to produce improved requirements and specifications for the streamlined depot maintenance process and the ITI-ALC system. With respect to these objectives, the following are possible recommendations and/or lessons that were learned.

- **Simulation is worth the effort.**

  The concept of applying $IDEF_3$ and WITNESS to a BPR effort provides significant benefits. Using the tools as stated by the $IDEF_3$ specifications and obtaining these benefits in total was a challenge. However, based on this application experience and the specifications for $IDEF_3$ and ProSim specifically, the following recommendations and/or lessons learned resulted from developing the "AS-IS" PM and the corresponding simulation.

- **ProSim did not implement the $IDEF_3$ rules completely as they were specified in Information Integration for Concurrent Engineering (IICE) $IDEF_3$ Process Description Capture Method, dated May 1992.**

  The $IDEF_3$ specification identifies five object states available throughout the project. The Entity Description Type is a pooled item in ProSim and can only be set to one type for the entire project. The $IDEF_3$ specification identifies junctions as providing a mechanism to specify the logic of process branching. ProSim junctions expand beyond branching logic and contain much of the functionality required by processes, such as creating objects or passing multiple created objects.

- **The translation from the process description to the simulation was one-directional.**

  The intent of $IDEF_3$, and implemented via ProSim, is to collect process flow and performance information so as to facilitate the development and execution of a simulation model within WITNESS. Following the translation from ProSim to WITNESS, a significant amount of effort is required to adjust and enhance the information in WITNESS before the simulation model is operational and available for verification, validation, and analysis.

  Because of this additional work required within WITNESS, and because the adjustments made in WITNESS can not be transferred back to ProSim, the benefits of the $IDEF_3$/ProSim representation and capabilities are lost once the first translation occurs.

  During the ITI-ALC program, this situation was addressed by maintaining two separate but correlated models. The $IDEF_3$/ProSim representation was maintained for display of the network while the WITNESS model was maintained for exercising the simulation.

- **The process model notation, as represented by ProSim, was not an effective presentation vehicle.**

  The information represented on a process flow network is very limited, reducing its effectiveness as a communication and analysis tool. To read and understand a network requires a labor intensive process of obtaining and integrating information from other sources.

  The readability of an $IDEF_3$ network could be significantly increased if the process flow information could be overlaid onto the network. For example, labels should be placed on the relationship arrows, conditions listed with the branches, and timing and resource requirements placed on processes.

  To support the presentation and readability of the $IDEF_3$ process flows for the ITI-ALC program, the functional models and performance data worksheets were used to discuss and validate the process flows. This approach improved the communications, but using just the performance worksheets proved to be the most effective for discussing and validating the process flows.

- **Scenarios, or small snippets of the entire process, help support the presentation of the process, but did not provide the foundation necessary to effectively analyze the performance of the depot maintenance process.**

  The $IDEF_3$ concept, and specifically the ProSim tool, was developed based on the idea that a large process flow could be developed and analyzed as small scenarios or snippets of the entire process. These small scenarios, consisting of five to ten processes, could then be presented on a single page.

However, this segmented approach limits the capability to evaluate the impacts caused by changes across the entire process flow. Evaluating the entire process as a unit was especially important when trying to identify operational bottlenecks when parameters in one segment were changed.

- **The data collection for the "AS-IS" PM and the simulation would have been approached differently if this modeling and analysis requirement had been established at the beginning of the ITI-ALC program.**

  The performance information required to develop the "AS-IS" PM would have been collected as part of the data collection for the "AS-IS" FM.

C.5 "TO-BE FM POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.2.1.4)

The following possible recommendations and/or lessons were learned during the development and use of the "TO-BE" FM.

- **Effective scoping of the functional model is important to maximize the benefits received from a BPR effort.**

  The focal point of the ITI-ALC program was the PDM mechanics within the Air Force's Air Logistics Centers. However, the scope was expanded at program initiation to include within the scope of ITI-ALC's BPR analysis the operational environments impacting the mechanic's performance effectiveness. This expanded scope provided the foundation needed to effectively streamline the mechanic process since much of the work performed by the mechanic was a duplication or continuation of the work performed by other individuals. Therefore, restricting the scope of the ITI-ALC program just to the mechanic would have limit the BPIs identified for the mechanic and would have reduced improved effectiveness provided by the proposed ITI-ALC system.

- **By including the cursory look at the engine and component environments allowed for the understanding for how the ITI-ALC system could aid the entire depot maintenance process.**

  While the focus of the ITI-ALC program was the PDM mechanic, the basic activities performed by all personnel throughout the depot have much in common and are tightly integrated. Making the minimal effort required to understand a larger perspective of the depot operations in terms of the commonality and integration provided the ITI-ALC team with the necessary background to maximize the benefits received from the improved depot maintenance process and the implementation of the ITI-ALC system. Therefore, using this broader perspective assured that the improvement concepts addressed all common aspects and assured that recommended improvements did not negatively impact other processes and personnel involved in depot maintenance.

C.6 "TO-BE" DM POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.2.2.4)

The following possible recommendations and/or lessons were identified during the development and use of the "TO-BE" DM.

- **The ERWin tool had significant limitations with respect to producing quality looking documentation.**

  Models are developed for use as analysis tools, therefore, they must be documented and presented in a manner that facilitates the analysis process. While the ERWin tool facilitated the development by controlling the migration of attributes among the entities, the tool did not allow for user control of the relationship layout among the entities. This resulted in data model that was difficult and time consuming to read and analyze. To correct this situation, the completed ERWin model was exported to the Design/IDEF tool which allowed the developer to rearrange the entities and relationships so as to maximize the readability and usefulness of the model.

C.7 SM POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.3.4)

During the development of the SM model, the following possible recommendations and/or lessons learned were identified.

- **Data flow diagrams are an excellent way to represent the system model.**

  The goal of the system model is to provide a transition from the functional and data requirements identified via the functional and data models to the design of the system that will satisfy those requirements. Using data flow diagrams provided an effective way of presenting this transition.

  The data flow diagrams supported a top-down approach and provided a leveling of information that reduced the complexity of information on any one diagram while allowing for increasingly more detailed information on decomposed diagrams. This top-down approach corresponded to that used to developed the functional model, resulting in a strong correlation between the "TO-BE" functional model and the system model.

  The data flow diagrams accommodated the specification of data stores and the interfaces with the data stores. The definition of these data stores provided an effective link to the entities specified within the "TO-BE" data model.

  The data flow diagrams accommodated the incorporation of system control activities and the specification of control flows among the activities and the interfaces to the user, the internal data stores, and the external database systems. Furthermore, a side benefit of this operate is that superior cost estimates based on Function Points can be derived from the models.

- **Although DFDs are an excellent way to represent the system model, the full benefit of the model can not be realized by those not knowledgeable in the model language.**

  Non-native languages have advantages over a native language because they are developed to efficiently present specific types of information. Native languages, on the other hand, have the advantage in that they are common and understood by a majority of people, even though they may not present the information as efficiently and accurately. This language difference causes some problems because the model developers prefer the non-native languages while system users often prefer the native languages. To maximize the benefit of these two perspectives, a two step approach should be used that enhances the communications between the two situation. First, users must be motivated and willing to take the effort to gain a reasonable understanding of the non-native language in order to fully appreciate the information contained in the model and to fully utilize the model. Second, the developers must be motivated and willing to supplement the non-native language with an ICON level abstraction to facilitate the understanding by the users. Development of a common understanding and effective communication maximizes the effectiveness and usefulness of the information produced.

C.8 BUSINESS CASE POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.4.4)

During the development of the business case, the following possible recommendations and/or lessons learned were identified.

- **Domain objective were not available.**

  There were no AFMC-wide objectives dealing explicitly with the ITI-ALC domain. As a result, the ITI-ALC team inferred two specific priority objectives from the many general objectives included in AFMC and ALC planning documents. Those specific objectives were reduced operating expense and aircraft flow days for organic aircraft PDM, as discussed in the business case.

  Also, there were no command-wide performance measures and targets (metrics) dealing with the domain that ITI-ALC was intended to affect. Accordingly the team inferred measures and targets from correspondence and data available within the depot maintenance domain.

- **Process improvement proposal structure required more than one improvement alterative.**

  This project team recognized that previous Information Technology (IT) investment projects typically presented decision makers with one alternative for improvement investment decisions. Therefore early on the ITI-ALC project incorporated an initiative to present a series of more than one option for the decision-maker. Each option more aggressive than the previous option in the series.

- **Two-way-blind test could not be fully implemented.**

  This project team recognized early in the program that there were not enough "equal" resources to conduct a true two-way blind test. One solution to this issue is to estimate enough resources in the project cost estimate. This is very expensive and may not be possible if equal team members cannot be found. If equal team members cannot be found a control team would also have to be formed to allow for the evaluation of variables between the two teams. In this age of "do more with less", this is not an acceptable approach. Using two core teams with one or two team members in both teams worked as long as everyone excepts the condition that the learning effect may bias the results. To minimize this bias, different team leaders were used and the SME was kept as "blind as possible" to the overall process so as not to subconsciously direct the two processes so they artificially converge. This plus an independent validation on the simulation half of the experiment (see the validation section above), allowed for results with small confidence intervals.

- **Another measure for economic analysis.**

  DoD and Air Force directives on economic analysis and the development of business cases contain two views of economic analysis.

  In the ITI-ALC project, the traditional view, defines the problem with the question, "what is the *maintenance cost* to accomplish organic aircraft PDM and how can we do it for less?" The answer obviously includes the cost of mechanics, engineers, and managers, the parts and raw materials incorporated into the aircraft product, the hangers and other facilities and the cost of supporting resources. It might be termed the in-house cost. It is not the major cost. This view deals with the problem from a systems perspective. It does not call into question the "out-of-service" costs associated with the relationship between the customer and the provider, AFMC. This problem is not new. It was raised by the DUSD(L) in 1995.

  In a May 30, 1995 memo, the DUSD(L) made a statement in response to GAO/AIMD-95-110 Depot Maintenance Standard Systems. The statement included, "While the Department appreciates the GAO acknowledgment of process improvements achieved to date in depot maintenance, the GAO fails to realize the magnitude of achieving significant reductions in cost and flow days equating to a 30% reduction in the cost of ship overhaul, or processing two additional B-1 bombers through an ALC because of reductions in flow days. To illustrate, due to the complete reengineering of work processes and use of BAIM, the Navy has reduced overhaul time for the 688 class submarine from 24 to 20 months and now estimates all future 688 workloads will take 18 months. To put that change in perspective, the previous average for similar work was $81 million per submarine. However, in addition to reducing the cost of overhaul, weapon systems are expedited to the warfighter, increasing mission readiness. In addition fewer systems in the repair cycle equates to fewer systems needing overall, thereby achieving even more dramatic savings."

  Without a value on the amount of time a system is out-of-service, the repair cycle days, it is difficult for managers to make investments to reduce them. The ITI-ALC system therefore developed a second view that combines total process and cost views into a total systems view. It includes the traditional view and takes into account the needs of and costs to the customer. In this view, the question is not only "what is the *maintenance cost*?"; but in addition, "what *are the costs to the customer*?".

What does the customer give up to obtain a PDM or incorporation of a modification package in an aircraft? A customer gives up two things. First, a customer pays the *maintenance cost* for each aircraft. That cost is relatively straightforward as reflected in the traditional view discussed above. Second, a customer relinquishes use of that portion of the aircraft's life spends in the maintenance process. For PDM the period will vary, but ranges from 100 to several hundreds of days per PDM cycle.

The cost to the customer of those days is less straightforward than the representing the *maintenance cost*. However, it was developed by the ITI-ALC team, based on similar industry practice.

To develop the cost to the customer, the ITI-ALC team obtained the Unit Flyaway Cost (UFC) for major aircraft in the USAF fleet from Air Force Instruction 65-503. This information for ten aircraft types is included in the table below. These items are included in the determination of a unit flyaway cost under Appropriation 3010 (Aircraft Procurement); airframe, propulsion, electronics, avionics, engineering change orders, if any, government furnished equipment, first destination transportation unless a separate line item, system and project management and system test and evaluation if funded by the aircraft procurement appropriation, warranties, recurring costs (both contract and in-house), nonrecurring cost (both contract and in-house), and advances buy cost (see Table C-1).

Table C-1. Aircraft Cost Information

Aircraft MDS	Inventory[1]	AFI 65-503 UFC (millions $)	UFC * 1.2 (millions $)	Value of One Aircraft Day ($)[2]
B-1	86	240.7	288.8	39566
F-15	584	24.2	29	3982
F-16	1588	14.5	17.4	2384
F-22	442	68.1	81.7	11197
E-3	29	114.3	137.2	18795
C-5	76	135.6	162.7	22300
C-130	877	14.5	17.4	2387
KC-135R	400	52.7	63.2	8664
C-141	223	41.2	49.5	6785
C-17	120	293.2	351.8	48199

[1] USAF Fact Sheets
[2] FY95 to FY94 conversion aircraft procurement weighted factor of 1.032.

Unit flyaway cost does not include: research, test, and evaluation appropriation expenditures, weapons and armament (except if part of the airframe, e.g., the 30MM GAU-81A gun on the A-10), peculiar ground support equipment, peculiar training equipment, technical data, initial spares and replacement spares.

In regards to flyaway cost and modifications, it is important to note that UFC reflects only those modifications which produced a new MDS. For example, the EF-111A was modified from the F-111A. Major aircraft modifications which do not produce a new MDS are not included. Thus, the unit flyaway cost for the B-052H reflects the unit flyaway cost as originally produced and then inflated to the constant dollars of a specific fiscal year. Since subsequent modifications to the B-052H did not produce a new MDS, the modifications are not included in the unit flyaway cost of the B-052H.

To account for research, development, test and evaluation, technical data, support equipment, etc., the ITI-ALC team increased UFC by 20%. The ITI-ALC team assumed 20 years in an aircraft life cycle.

To calculate the value of one aircraft flow day the team applied this formula:

$$\textit{Cost to the Customer for an Aircraft Flow Day} = \frac{\textit{(UFC)(1.2)}}{\textit{(Life Cycle in Years)(365 Days)}}$$

Using this approach, the value of MSIP F-15 flow days of 174 days, is $692,868 per aircraft. The value of the 154 F-15 flow days provided to a customer, if flow days could be reduced to 20 days, is $613,226 per aircraft. The ITI-ALC team estimated Primary Aircraft Authorization (PAA) fleet sizes from USAF fact sheets or public literature. For a fleet of 584 F-15 aircraft, the value of the returned flow days is $358,125,152 over one 5 or 6 year PDM cycle.

C.9 SSS POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.5.4)

The process used to develop the ITI-ALC SSS was fairly rigorous, systematic, and successful. There were several possible recommendations and/or lessons learned from implementing this process.

- **SSS development workshop should be longer.**

  The workshop was three days long which only allowed time for revising the user requirements. The workshop should be five days long to allow time to examine and revise all requirements in the SSS with focus on the user requirements, external interface requirements, and segment descriptions and requirements.

- **SSS workshop instead of one of the three deliverables.**

  If a workshop is used as a means to develop the SSS, there should only be two deliveries of the document. There should be one delivery (preliminary final) reflecting the results of the workshop and a second delivery (final) approximately three months later to address any outstanding details or issues resulting from customer review of the post-workshop version. The premise of two deliveries stems from the idea that the workshop is supported by the appropriate personnel that can and should influence the requirements within the SSS, negating the need for three deliveries to achieve the desired content level.

- **Iterative requirements development is required.**

  The primary categories of developmental requirements within the SSS are functional requirements (representing user requirements), external interface requirements, and segment requirements. The functional requirements should be defined first and should determine the need and provide the basis for the external interface requirements and the segment requirements. As requirements are developed, each category (functional, external interface, and segment) should be revisited and revised accordingly (iterative process) until "all" requirements have been defined for the system.

- **The concept for how to specify and organize an effective SSS was not consistent among all individuals involved in its development, even though a DID was identified within the contract.**

  The SSS was one of the key documents developed during the ITI-ALC program in that it specified the detailed requirements for the "TO-BE" ITI-ALC process as well as the technologies used to implement the process. The true success of the ITI-ALC program will not be determined until the SSS is used as the guide for designing, developing, and implementing the ITI-ALC system. Given the importance of the SSS, the "correct" DID, and a full understanding of that DID, should have been established early-on by all representatives of the customer and should have been reinforced throughout the program. The reinforcement would ensure that new program personnel understand the history and goals of the work performed and would eliminate the possibility of unnecessary program direction changes. These variations in SSS expectations and concepts within the customer team required significant time and effort to discuss and a large amount of rework.

C.10 SSDD POSSIBLE RECOMMENDATIONA AND LESSONS LEARNED (REF.; SECTION 3.6.1.4)

The following are possible recommendations and/or lessons that were learned during the development the SSDD.

- **Overlap/parallel development of project deliverables.**

  While overlapping the development of project documents such as the SSDD and the SSS helps reduce the project's schedule, this overlap also can cause extra, non-value-added work when changes are made, due to the ripple effect. The solution used on this project didn't eliminate this rework completely, but did reduce it to tolerable levels. The primary way this was done was to structure the development approach to take advantage of the iterative nature of the system development process (see Figure 3-11). The "TO-BE" models represented requirements for the system and were baselined early enough in the process to be used to develop the SM. The SM then became the major input into the SSDD. Because both the SSS and the SSDD were ultimately derived from the same sources, the SSDD fulfilled all the requirements identified in the SSS even with them being developed almost simultaneously. This fact was validated using the traceability process outlined above. This innovative approach to parallel development allowed shorter schedule time as well as flexibility to change.

C.11 IMIS DEMO ANALYSIS POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.6.2.4)

During the performance of the IMIS Demo Analysis, the following possible recommendations and/or lessons learned were identified:

- **System documentation is needed.**

  Comparing a developed system with a system undergoing requirements definition presented a unique challenge that would have been reduced if the documentation for the developed system had been provided.

- **Working with the software of the developed system was very useful for determining the functionality of the system.**

  Reading the documentation for a system helps understand the intended functionality of the system and provides the mechanics necessary to maneuver within the system. Having gained this fundamental understanding, getting hands-on experience is the only way of understanding the real system capabilities necessary to perform an indepth evaluation and comparison.

- **Development system source code would have enhanced the comparison.**

  The comparison document could have provided another level of usefulness if the software code had been provided. The code would have allowed the identification of the changes required in the code rather than the functions that require change.

C.12 DEMONSTRATION PLAN POSSIBLE RECOMMENDATIONS AND LESSONS LEARNED (REF.; SECTION 3.7.4)

The following observations were made as possible recommendations to improve the results and efficiency of future efforts of this nature:

- **The title of the resulting document for this effort should have been; Experiment Design Document for the Demonstration of the Efficacy of the ITI-ALC System and BPIs.**

  It was obvious from ITI-ALC's Statement of Work (SOW) that AL/HRGO wanted a plan for an experiment that demonstrates the improved effectiveness and efficiency of mechanics and other depot PDM personnel when using new processes and technologies described in the *System/Segment Specification* and the *ITI-ALC Business Case*. This intent was not obvious from the title of the document per the CDRL list. A "demonstration" denotes a certain informal approach to the effort and a "test" would most likely be confused with a "System Test" which has a different intent (the intent of all formal system/software testing is to find errors in the system/software [Rubey86]) then what will be done for Phase II of ITI-ALC. In the future, AL/HRGO should name similar efforts as "Experiments".

- **Adjust the development schedule for the Demostration Plan.**

  Before time and resources are spent on designing an experiment, customer resources should be allocated to the review, analysis, understanding and critiquing of the results of that effort. If another such program is conducted in the future, AL/HRGO should consider removing this tasks from the Phase I SOW due to it's premature nature. This task is better suited to a time closer to the actual implementation of the plan.

- **Cost consideration for the experiment should be included.**

  The test or demonstrations identified in the deliverable for this effort did not presume to evaluate the cost of performing the tasks identified in the experiment or the cost of building a demonstration system to conduct those tasks. However, the design was developed so that one half of the experiment could be conducted with little of no interaction with the second half, therefore allowing for a truncated test/demonstration. Another way to do this would be to get potential users involved much earlier (e.g., at the second release of the SSS) in the process to define which functional requirements they would like to see in a test/demonstration. This information would then have to be made available to the contractor performing the experiment design effort.

- **More emphases on functional demonstration verses system interface.**

  To ensure a cost effective demonstration, more emphases should be put on prototyping the functional capabilities of the ITI-ALC system verses making something that will evolve into a production system. One aspect of "production level" software is that too much time/resources are spent in building "real" system-to-system interfaces with legacy and emerging system. Most of the data obtained from the supporting system included in the ITI-ALC design can be simulated/derived, allowing for more resources devoted to building a system that helps the user understand the ITI-ALC BPI concepts and that is flexible enough to try many different ideas. The industries trend toward "evolutionary" prototypes is an unrealized potential because the nature of prototypes and the nature of "production" software are mostly mutually exclusive. This lesson highlights and utilizes the flexibility and modularity of the ITI-ALC design per the SSDD and the SM.

APPENDIX D. DATA COLLECTION APPROACH

D.1 DATA COLLECTION DISCUSSION

The various models developed as part of the ITI-ALC program formed the foundation for specifying the improved depot maintenance process and for establishing the requirements and specifications needed to identify and select the technologies capable of implementing the improved PDM process. Model development began as the first step in the data collection effort and guided the overall data collection effort. The various perspectives of the depot maintenance process provided by the models, the close interaction among the models, and the traceability of requirements from the users to the design via the model ensured that requirements were developed for a complete, user-oriented depot maintenance process and ITI-ALC system.

Figure D-1 presents an overview of the model development effort. The data was collected from the users and formally documented in the DCD, and supplemented with notes, collected forms and documents, and tape recordings. This information was then analyzed and used to developed the set of "AS-IS" and "TO-BE" models.

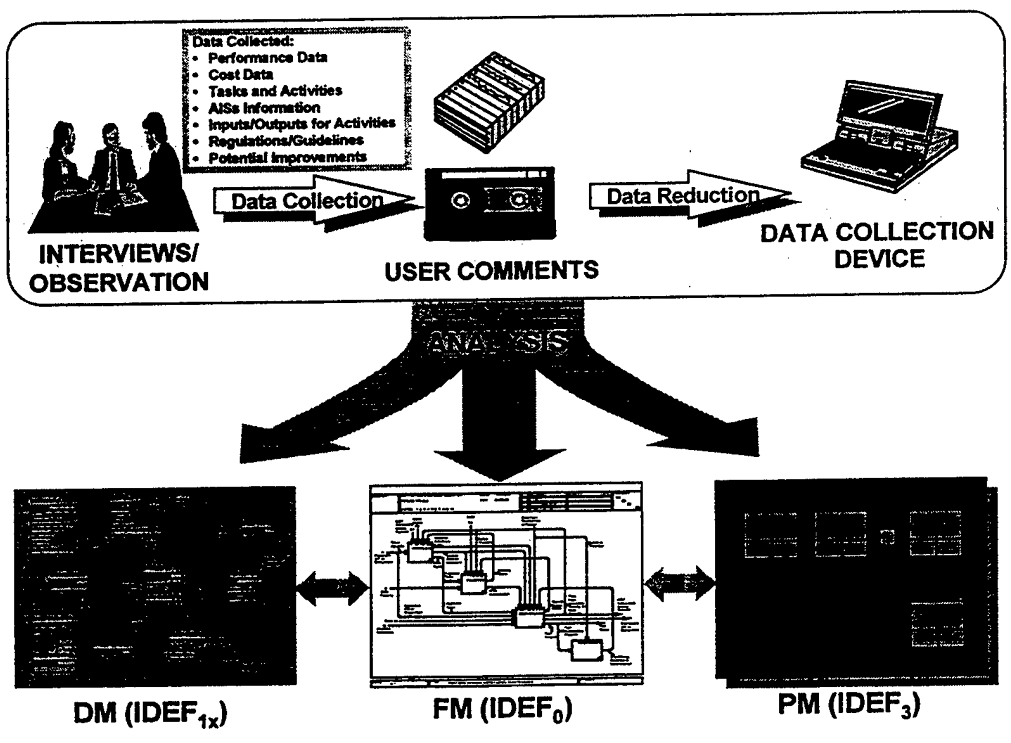


Figure D-1. Data Analysis and Model Development Process

The "AS-IS" FM was develop by using the collected information to refine and expand the strawman model. Using the name of a strawman activity as a pointer into the DCD, the details of that activity were selected from the DCD via a variety of reports. This focused information was analyzed and organized to produce the decompositions for that strawman activity. The tapes, notes, forms, and the ITI-ALC team's functional experts were used to augment the information from the DCD.

Once the Axx level of the "AS-IS" FM were relatively firm, the development of the "AS-IS" DM was initiated. This development started with a listing of the arrows extracted from the "AS-IS" FM. The arrow listing was supplemented with information from the DCD, tapes, notes, forms, and the ITI-ALC team's functional experts. The "AS-IS" models were not developed independent of one another. Because each of the three models represented the same process, but from a different perspective, their development was done in a coordinated manner. As ideas, missing information, etc. were identified in one model, that insight was transferred to the other model development efforts, the corrective action taken, and the resulting information made available to each of the modeling efforts. This close coordination helped to ensure that each of the models was complete and accurate, and there was consistency and traceability among the models.

The "AS-IS" models were then analyzed to identify the BPIs for the improved process. These BPIs were used to modify the "AS-IS" models to represent the improved process definition via the "TO-BE" models.

The goal of the ITI-ALC program was to analyze the PDM process within each of the five ALCs and develop a generic representation of a "composite" ALC. To ensure an accurate and complete description of the current depot maintenance process rather than a theoretical perspective of what the process should be, data collection was performed primarily by interviewing functional experts and users, as opposed to collecting information solely from reading regulations and manuals. In addition to the process description information, the collected data also included user ideas about what is wrong with the current process and how it could be improved.

The strategy for the data collection effort, as shown in Figure D-2, used a set of interview criteria established to guide the development of interview kits for the data collection efforts. The criteria included an identification of job functions within the ALCs, the "Select Set" of aircraft and components, the types of maintenance to be performed on the elements of the "Select Set", and the strawman model. The interview criteria also supported identification of the specific roles to be interviewed at each ALC.

The information collected from the ALCs was recorded in the form of notes and tape recordings. This information was then organized and documented in the DCD database. As the information was analyzed and the "AS-IS" models developed, additional data requirements were identified. This information voids were filled by using targeted follow-up interviews. This information was analyzed and used to refine and expand the strawman model into the "AS-IS" functional model.

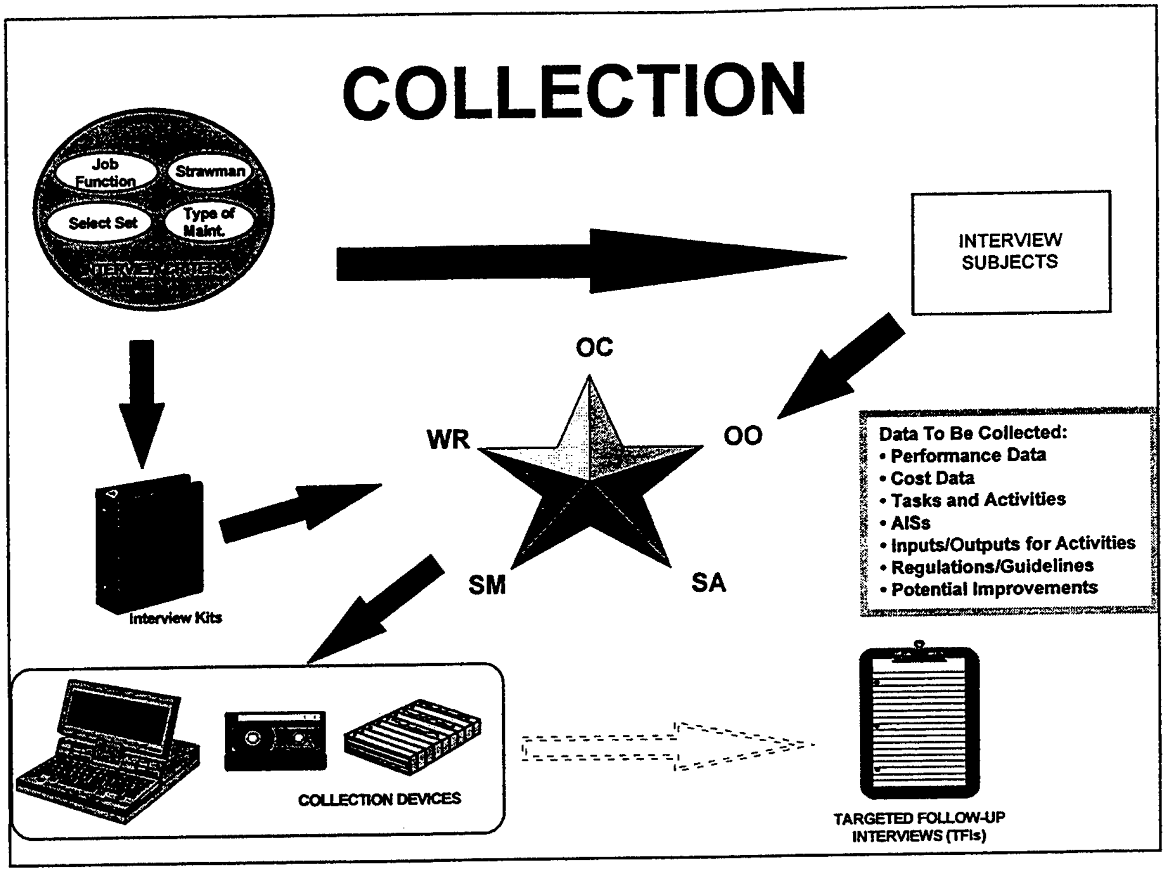


Figure D-2. Data Collection Strategy

The initial data collection efforts focused on information required to develop the "AS-IS" functional and data models. Later in the ITI-ALC program, a requirement was added to develop and apply process and simulation models to the analysis effort. As a result of these additional program requirements, the data collection for the process flow and simulation models was addressed separately rather than as a integral part of the overall data collection effort.

D.1.1 Strawman Functional Model

A strawman model was developed as the first step in the data collection effort. The strawman provided a common reference point for discussing the PDM process among all personnel associated with the ITI-ALC program; the structure for collecting, storing the collected data, and analyzing the collected data; and the starting point for developing the "AS-IS" functional model. The scope, viewpoint, and analysis objectives for the strawman model were established through the goals and requirements defined for ITI-ALC program.

The strawman was initiated through a joint effort between SRA and ARINC personnel, and refined and expanded with information gained from a variety of sources. These sources included the Joint Logistics Systems Center (JLSC's) *Improved Functional Baseline (IFB) IDEF0 Model and Glossary* dated October 1993, the analysis of depot maintenance regulations, reviews of related programs, and subject matter experts available as part of the ITI-ALC team.

The strawman was developed at the A0-diagram level, and extended to include A-1 and A-2 diagrams which related the ITI-ALC's PDM focus with the total depot maintenance process and the total Organizational, Intermediate, and depot maintenance process, respectively. Using scenario-based walkthroughs, the model was reviewed with AL/HRGO personnel to verify the accuracy of the boundaries within the depot maintenance to be addressed during the ITI-ALC program, thus setting the scope of the entire program.

With the program boundary confirmed, the strawman model was reviewed by subject matter experts available on the ITI-ALC team to verify the accuracy of the model. These reviews were accomplished through a combination of readership cycles and scenario-based walkthroughs. The completed strawman model was detailed enough to provide a common reference for ALC personnel and the ITI-ALC interview teams during the data collection process, but general enough not to bias the interview.

D.1.2 Identification of the Information Sources Discussion

The accuracy and effectiveness of the information collected to describe the "AS-IS" view of the depot maintenance process was critical to the overall success of the program. To optimize success of the data collection effort, the process represented in Figure D-3 was used to identify the specific information sources. The program objectives and the strawman model specified the requirements for the types of information needed, the types of information needed provide criteria for the sites at which the various data would be collected, and the information type requirement along with the selected sites helped to identify the specific individuals, documents, etc. from which the information would be collected at each ALC. Knowing the specific sources then helped to select the most effective data collection method.

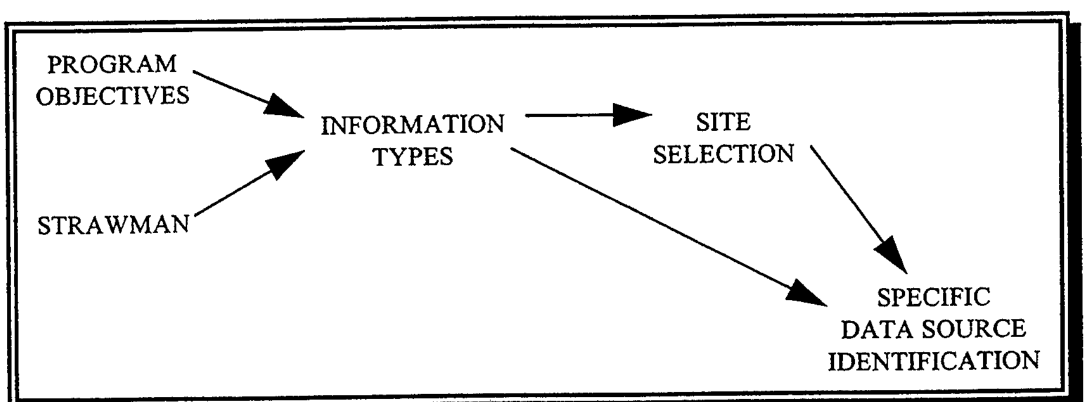


Figure D-3. Identifying Data and Data Sources

D.1.2.1 Information Types Discussion

The types of information required to describe the "AS-IS" depot maintenance process is driven by the program objectives, with the scope of the information defined through the strawman model. The program objective was to perform a BPR analysis on the PDM portion of the depot maintenance process, with a limited look at component repair. To perform this analysis required a definition of the process from functional, data, and operational perspectives. Therefore, it was necessary to identify the functions performed within depot maintenance, the information and items used by and produced by each function, the interfaces among the functions, the business rules describing the relationships and operational usage of the data, the flow of information and products through depot maintenance, the dynamic characteristics of each function performed, and the resources used to exercise each function.

To gain an accurate representation of the current PDM process, with a limit look at component repair, a select set of system was developed, and listed in Table D-1, along with their system category.

Table D-1. The Select Set of Systems

"Select Set"	**Category**
F-16	Light Weight A/C
F-15	Light-Weight A/C
F-22	Light Weight A/C
C-135	Heavy Weight A/C
C-5	Heavy Weight A/C
F110	Engine
F100	Engine
EF-111 Tactical Jamming System	EW
LANTIRN	Avionics
Advanced Composites	Structures
Landing Gear	Structures
Fuel Controls	Hydro/Mechanical
Constant Speed Drives	Hydro/Mechanical
Generators	Electro/Mechanical

The strawman model provided the scope and viewpoint needed to focus in on the information associated with this select set of systems and also provided a structure for collecting and storing the data, along with an initial identification for possible sources of the data.

D.1.2.2 Select Set Discussion

The select set of systems were mapped against the five ALCs to produce system profiles for each ALC, as represented in Table D-2. Using these profiles, the site at which the information for each system within the select set was maintained. This mapping allowed for the selection of what system maintenance data would be collected at each ALC.

Table D-2. The Select Set Mapped to ALCs

"Select Set"	Category	ALC(s)
F-16	Light Weight A/C	OO-ALC
F-15	Light-Weight A/C	WR-ALC, SM-ALC
F-22	Light Weight A/C	SM-ALC
C-135	Heavy Weight A/C	OC-ALC
C-5	Heavy Weight A/C	SA-ALC
F110	Engine	OC-ALC
F100	Engine	SA-ALC
EF-111 Tactical Jamming System	EW	WR-ALC
LANTIRN	Avionics	WR-ALC
Advanced Composites	Structures	SM-ALC, OC-ALC
Landing Gear	Structures	OO-ALC
Fuel Controls	Hydro/Mechanical	SA-ALC, OC-ALC
Constant Speed Drives	Hydro/Mechanical	OC-ALC
Generators	Electro/Mechanical	SM-ALC

D.1.2.3 Source Identification Discussion

With the types of information identified and the appropriate sites selected, the next step was to identify the specific sources from which the information would be collected at each ALC site. These sources of information focused on the maintenance personnel within each of the ALCs. Based on the knowledge of the ITI-ALC team's functional expert and the high-level perspective provided by the strawman model, a list of personnel skill types, or roles, were identified that could provide a majority of information needed. The results of this mapping are presented in Table D-3.

Table D-3. Strawman vs. Skill Matrix

Strawman Activity	**Performing "Roles"**
A0.1 Integrate Work Requirements	Planner Scheduler Aircraft Manager
A0.2 Allocate Resources	Scheduler Aircraft Manager First-Line Supervisor
A0.3 Acquire and Issue Parts and Supplies	Mechanic/Specialist Aircraft Manager Scheduler In-House Supply
A0.4 Repair Engines and Components	Aircraft Manager Mechanic/Specialist
A0.5 Maintain and Repair Aircraft	Aircraft Manager Mechanic/Specialist
A5.1 Select Task	Aircraft Manager Mechanic/Specialist
A5.2 Obtain Guidance Material	Mechanic/Specialist
A5.3 Order Parts	Mechanic/Specialist Scheduler In-House Supply
A5.4 Perform Task	Mechanic/Specialist
A5.5 Perform Functional Check Flight	Flight Test Pilot Inspector
A5.6 Record Maintenance Information	Aircraft Manager Scheduler

The final step in the source identification process was to identify specific individuals responsible for the designated roles at each ALC. To facilitate this selection process, as well as facilitate the overall data collection effort, a Point-of-Contact (POC) was arranged at each site. Biographies were developed and provided to the focal point at each ALC. This biographies provided a description of the skills that had been identified as information sources. Using these biographies as a guide, the POC selected specific individuals who could effectively provide the required information and to arranged for their time during the scheduled data collection trip.

As the data collection effort progressed, supplementary information sources such as forms, reports, regulations, process observation were identified and used.

D.1.3 Data Collection Materials

With the information collection goals established along with the initial definition of the information sources, the next step was to establish how the information would actually be collected. The data collection material that were developed were interview kits, the data collection team organization, and data collection procedures definition.

D.1.3.1 Interview Kits

The objective of the Interview Kits was to provide all the information needed the support the data collection effort. An interview kit contained the following materials:

- **Section A: Interviewer's Guide**

  A outline defining the general steps to be accomplished during the interview.

- **Section B: Introduction**

  An overview of the ITI-ALC program that provides the interviewee with a description of the program for which the information is being collected.

- **Section C: Privacy Act Signature Collection Form**

  A agreement that is signed and dated before an interview can proceed. This agreement assures that the interviewee is participating in a voluntary manner and that all information provided will not be documented in a manner that links the information back to the individual.

- **Section D: Biography**

  A form which documents the title and skill level of the individual when an interview approach is applied.

- **Section E: Results Package Cover Sheets**

  A form which links a unique number to the interview along with the identification of the interviewers.

- **Section F: Strawman Model**

  The IDEF0 strawman model, along with its associated text. This strawman model is used as the focal point for discussing the process being analyzed.

- **Section G: Interview Numbers (allocated according to the ALCs and interview team)**

  A set of interview numbers assigned to each data collection team. For the ITI-ALC program, this list included a large set for each ALC. This large set for the ALC was then subdivided into subsets and assigned to each team.

- **Section H: Select Set of Reparables per the ITI-ALC Proposal**

  A listing of the select set of reparables to be focused on at each ALC.

- **Section I: Interview Breakout Schedule**

  A table which summarizing the administrative information related to each interview. This table was used to schedule the planned interviews and to document variations to the schedule.

- **Section J: Question Sets**

  A set of questions that were developed and used to guide the data collection effort. These questions were not meant to be used in a direct question and answer (questionnaire) manner, but rather as a flexible guide or check point to ensure all information was collected during the session. The question set contained generic questions that were applied across all nodes of the strawman model as well as specific questions were developed that targeted areas not well understood by the ITI-ALC team.

- **Section K: Acronyms**

  A list of acronyms previously identified as being used within the process being analyzed. During the data collection, these acronyms were verified and new ones added as they were identified. They provided a quick reference for the data collection team.

- **Section L: Data Collection Form**

  Blank pages on which the data collection team could take notes during the data collection sessions.

- **Section M: In-Briefing (developed by AL/HRGO)**

  A set of briefing charts used as the first step at each ALC to present the ITI-ALC program and the objective of the data collection effort.

- **Section N: Miscellaneous (legacy system definitions, interview team composition, etc.)**

  Blank pages on which the data collection team could take notes about legacy systems and other information that could be of value in the program but not necessarily within the boundaries of the program.

There exists a number of data collection procedures that could have been used to gather the necessary information for the ITI-ALC program from the users and functional experts. These techniques include questionnaires, group workshops, observation, documentation review, and user interviews. For the ITI-ALC program, all these approaches except for the questionnaires were used to some degree, but the primary approaches were user interviews and operational observations.

The documentation reviews were used to gain an initial understanding of the depot maintenance process and to analyze the documents and forms collected from the ALCs. These data supplemented data from other sources.

Guided by the interview kits, many of the interviews were held away from the interviewee's worksite so as to allow the interviewee to focus on the interview and not be distracted by daily activity going on within the depot. The remaining interviews were held on-site to provide a first-hand understanding and appreciation of the depot maintenance work performed and the actual access and use of information.

The observations were implemented primarily in the form of facility tours that allowed for direct interaction with the users. In addition, a number of visits were made to the specific areas within the depot to observe the work performed by specific individuals who played a critical role in the depot maintenance process.

Using walkthroughs, workshops were used primarily to validate the models. However, during these workshops, additional depot maintenance process data was also collected and used to refine and expand the various models.

D.1.3.2 Data Collection Teams

The ITI-ALC team's emphasis on, and sensitivity to, the need for accurate data collection and analysis demanded that the data collection structure and teams be developed very carefully. Each data collection effort was planned so as to address the data required to be collected from the both the site and the specific source.

A key element in ensuring the accuracy and completeness of the data collection was to establish an effective set of data collection teams. Each team was limited to two individuals; a modeling expert and a functional area expert. The presence of too many interviewers on a team has a tendency to intimidate and confuse a subject, resulting in invalid data.

The primary responsibility of the modeling experts was to guide the interview as specified in the interview kits so as to ensure that data collected was sufficient for the development of the various models. The primary responsibilities of the functional area experts were to ensure the data collected encompassed all aspects of the depot maintenance process, to ensure the modelers were correctly interpreting the subject's information, to ask appropriate questions to ensure information accuracy and completeness, and to act as a sounding board for discussing the modeler's understanding of the maintenance process.

As a member of the overall data collection team, but not specifically assigned as a member of a two-person data collection team, a observer had the freedom to attend any of the interview sessions. The responsibility of the observer was not to take an active part in the interview but rather to monitor all the data collection teams to ensure consistency of data collection across all teams.

D.1.3.3 Site Visit Strategy

For data collection visit to an ALC started with an in-briefing and tour. This was followed with scheduled sets of interviews and some process observations when possible and appropriate. At the end of the week an out-briefing was offered to the selected personnel at the ALC.

For each interview, the strawman model was used as the basis for discussion and provided two main functions. One, it demonstrated to the subjects the level of knowledge possessed by the data collection team and provided the subject with a reference point at which to direct their discussion. Two, the strawman model provided a process boundary and therefore helped to focus and direct the data collection effort.

During each interview, data was collected in a number of forms. Notes were taken either electronically or handwritten, depending on the preference of the team. Each interview was also recorded with a audio tape, with the subject being given the opportunity to declined having the recording made or to stop the recording at any point during the interview. As references were made to current information systems and data recording forms, information about the systems and copies of the forms were requested and obtained. A list of these information systems and forms was maintained among the data collection teams to provide a point of reference and to identify that information had already been requested and or received about the systems and forms.

Following each interview, the team would meet to discuss the process understanding gained from the interview, to identify specific information requirements that must be addressed during subsequent data collection efforts, and to organize and enter the information into the DCD.

At the end of each day, the data collection teams met to discuss their data collection efforts for the day. These discussion included new understandings that had been gained, information voids that had been identified, and specific data collection requirements for the next day.

D.1.4 Managing the Collected Data

A significant effort was required to collect the information from the users and other sources for its use in understanding, analyzing, and developing the improved depot maintenance operational concept. To maximize the benefits received from the information required that the information be effectively managed.

Shortly after each data collection interview, the team organized the information and entered it into the DCD. There were two reasons for entering the data as soon as possible. First, the sooner the information was entered into the DCD, the sooner the information was available for use in refining and expanding the models. Second, the sooner the information was entered into the DCD the completeness and accuracy of the information was increased due primarily to the memory and note taking capability of the interviewers.

The information for each interview was identified by an interview number which related it back to the ALC and the skill from which it was collected. From the collected information, activities were identified, short narratives written about each activity, and the inputs, outputs, controls, and mechanisms for the activities identified. In addition, the interactions among various activities were also identified.

To reduce the duplication of effort during the data entry effort, a standardized list of activities were maintained in the DCD. As an activity was identified for the collected data, a quick search was made to determine if that activity had been previously entered. If the activity did exist, the associated information was reviewed and updated as necessary. If the activity did not exist, the appropriate information would be entered into the DCD.

The tapes were labeled with the interview number, notes were placed in a folder labeled with the interview number, and the forms were organized in a three-ring binder with an form index placed in front for a quick reference.

D.1.5 Tool Selection

The tools used to support the data collection process were the interview kit, a tape recorder and the Data Collection Device.

D.1.5.1 Interview Kit

The interview kit was implemented as a manual tool to provide guidance and support during the data collection effort. This kit as described in Section D.1.3.1 included, among other information, the types of information to be collected and a means of collecting notes during the data collection efforts.

D.1.5.2 Tape Recorder

During a data collection session, significant amounts of information are presented. However, due to a number of factors, much of this information could not be fully understood or appreciated at the time, or could not be retained following the data collection effort. Therefore, to ensure the full potential of the data collection, tape recorders were used to capture everything that was said. These tapes then provided a valuable resource to revisit the data collection efforts over a period of time so that the full value of the interviews was acquired.

D.1.5.3 The Data Collection Device

The DCD was a data base tool used to support the data collection and model development efforts. The DCD was developed using COTS data base management system (DBMS) 4th Dimension by ACI US, Inc. as an engine and to run on a portable computer that could easily be taken on the data collection trips. The DCD was capable of coordinating the collected data with the structure of the strawman model, capturing all of the data anticipated to be gathered during data collection, and allowing for data entry and access in a way that was intuitive to the data collectors and model developers.